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62d Congress, 2d Session | SENATE | Document No. 305

MEXICAN COTTON-BOLL WEEVIL

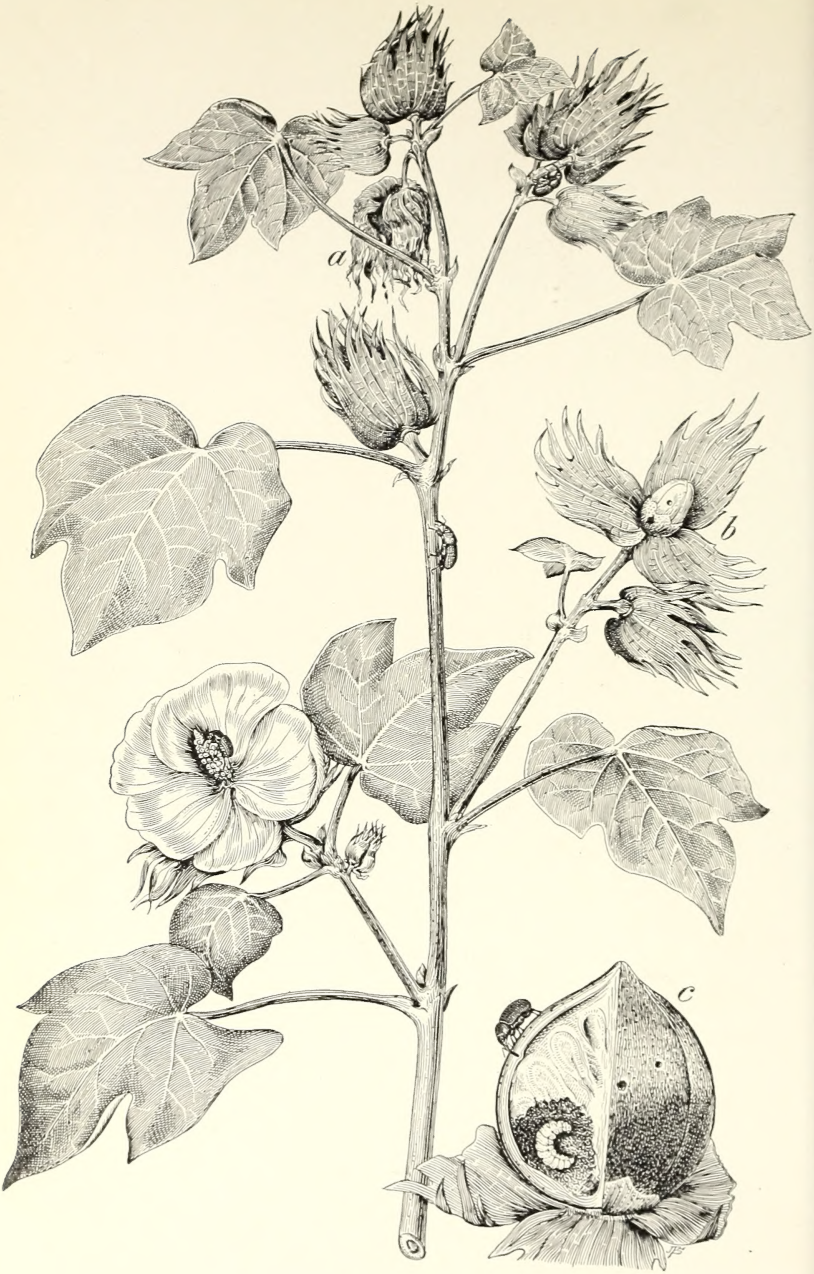
Ent. Bulletin no. 114.

MESSAGE FROM THE PRESIDENT OF THE UNITED STATES

TRANSMITTING

A COMMUNICATION FROM THE
SECRETARY OF AGRICULTURE
SUBMITTING A REPORT ON THE
MEXICAN COTTON-BOLL WEEVIL

WASHINGTON
1912



COTTON PLANT ATTACKED BY BOLL WEEVIL.

a, Hanging dry square infested by weevil larva; *b*, flared square, with weevil punctures; *c*, cotton boll, sectioned, showing attacking weevil and weevil larva in its cell. (Original.)

62D CONGRESS
2d Session

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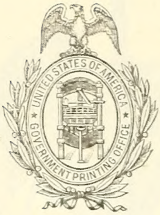
UNITED STATES OF AMERICA
GOVERNMENT PRINTING OFFICE

LETTER OF TRANSMITTAL.

To the Senate and House of Representatives:

I transmit herewith for the information of the Congress a communication from the Secretary of Agriculture, accompanying the manuscript of a report on the Mexican Cotton-boll Weevil: A Summary of the Results of the Investigation of this Insect up to December 31, 1911. (Bulletin No. 114, Bureau of Entomology.)

The report contains valuable information of great public interest to cotton planters of this country and those depending upon the cotton-plant industry, and I cordially indorse the recommendation of the Secretary that the report be printed for distribution by Congress as well as by the department.

Wm. H. Taft.

The White House, *February 12, 1912.*

LETTERS OF SUBMITTAL.

Department of Agriculture,
Office of the Secretary,
Washington, February 8, 1912.

To the President of the United States.

Mr. President: I have the honor to submit herewith, for your information and that of the Congress of the United States, a bulletin entitled "The Mexican Cotton-boll Weevil: A Summary of the Results of the Investigation of this Insect up to December 31, 1911," by Messrs. W. D. Hunter and W. D. Pierce of this department. This is an elaboration of a bulletin published in 1905 and of which a special edition was ordered by Congress. Since that date the weevil has spread throughout the State of Louisiana and has entered the States of Arkansas, Mississippi, and Alabama, and threatens to spread throughout the entire cotton-growing area east of the arid regions. In the course of this eastward and northward spread, new conditions have been encountered; the habits and life history of the weevil have undergone some change, and it has met with new parasites and natural enemies. There is a great demand among the cotton planters of this country and among those dependent upon the cotton-planting industry for the information contained in this bulletin, and, in view of this fact, I respectfully recommend that this report be transmitted to Congress, together with the maps, illustrations and diagrams accompanying it, to be printed by order of Congress; and I further recommend that not less than 10,000 copies be printed for the use of this department, in addition to such number as Congress may order for the use of its Members.

I have the honor to remain, Mr. President,

Very respectfully,

James Wilson, *Secretary.*

Department of Agriculture.
Bureau of Entomology,
Washington, D. C., January, 1912.

Sir: I have the honor to transmit herewith and to recommend for publication a manuscript entitled "The Mexican Cotton-boll Weevil: A Summary of the Results of the Investigation of this Insect up to December 31, 1911," prepared by Messrs. W. D. Hunter and W. D. Pierce, of this bureau.

This manuscript contains in the briefest possible space an account of the exhaustive investigations of the Mexican cotton-boll weevil which have been conducted by this bureau for some years past. The last comprehensive bulletin on this subject was issued in 1905 and is now far out of date. There is urgent demand for information on this important pest, and this demand will undoubtedly continue as the insect invades new regions.

Respectfully,

L. O. Howard,
Entomologist and Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Early in 1905 the Bureau of Entomology published as Bulletin 51 an account of the information concerning the Mexican cotton-boll weevil which was available at that time. Since 1905 the work on the investigation of this important insect has been continued by the Bureau of Entomology and by various other agencies. As the result of this recent work certain features of the life history of the pest have received full treatment in publications of the bureau. This is the case with hibernation,[1] natural control,[2] parasites,[3] proliferation,[4] and repression.[5] Important contributions have been made by State agencies. The result has been that the original bulletin has been out of date for some time. On many topics the amount of information now available is more than double that at hand at the time the previous publication was issued. Moreover, it seems advisable that the history of the pest in the United States and an account of the losses occasioned by it should be brought up to date. For these reasons the present publication has been prepared to include all of the more important available information concerning the boll weevil. It is based upon Bulletin 51, from which many extracts have been used, and will supersede that publication.

In the nature of the case it is impossible to include all of the data which have been published with reference to certain phases of the life history of the boll weevil, such as hibernation and parasite control. In all such cases, however, the main essentials regarding these special topics have been incorporated. Persons who desire more detailed information may consult the various special publications, which are still available.

As might be supposed the accumulation of many additional data has necessarily changed some of the conclusions drawn in the earlier publication. It is to be noted, however, that these changes are generally of little consequence.

The investigation of the boll weevil was begun by the then Division of Entomology in 1895 and has been continued, more or less constantly, to the present date. The vast amount of information which has thus been accumulated is to be credited to a large number of entomologists, many of whom are now doing work in other fields, The earlier investigations of the weevil were conducted by Dr. L. O. Howard and Messrs. C. L. Marlatt, C. H. T. Townsend, E. A. Schwarz. and Frederick Mally. The State officers who have assisted materially in this work have been the entomologists of Texas, Messrs. E. D. Sanderson, A. F. Conradi, C. E. Sanborn, and Wilmon Newell; of Louisiana, Messrs. H. A. Morgan, Wilmon Newell, J. B. Garrett,

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[1] Bull. 77, Bur. Ent., U. S. Dept. Agr., 1909.

[2] Bull. 74, Bur. Ent., U. S. Dept. Agr., 1907.

[3] Bull. 100, Bur. Ent., U. S. Dept. Agr., 1912.

[4] Bull. 59, Bur. Ent., U. S. Dept. Agr., 1906.

[5] Farmers' Bull. 344, U. S. Dept. Agr., 1909.

T. C. Barber, H. Dean, M. S. Dougherty, A. H. Rosenfeld, and G. A. Runner; of Oklahoma, Messrs. C. E. Sanborn and A. L. Lovett; of Arkansas, Dr. George F. Adams; of Mississippi, Messrs. Glenn W. Herrick, R. W. Harned, S. F. Blumenfeld, and R. N. Lobdell; and of Alabama, Dr. W. E. Hinds and Messrs. W. F. Turner and I. W. Carpenter. The work has been facilitated by the commissioners of agriculture of the various States, including Col. Charles Shuler, former commissioner of agriculture of Louisiana, Mr. H. E. Blakeslee, commissioner of agriculture of Mississippi, and Mr. F. W. Gist, former commissioner of agriculture of Oklahoma.

The agents of the Bureau of Entomology who have contributed to this bulletin are: Messrs. F. C. Bishopp, J. C. Crawford, R. A. Cushman, F. L. Elliott, A. F. Felt, C. W. Flynn, J. B. Garrett, W. H. Gilson, S. Goes, G. H. Harris, W. E. Hinds, W. H. Hoffman, T. E. Holloway, C. E. Hood, W. A. Hooker, R. C. Howell, C. R. Jones, B. T. Jordan, O. M. Lander, Thomas Lucas, E. A. McGregor, J. D. Mitchell, A. C. Morgan, A. W. Morrill, D. C. Parman, T. C. Paulsen, H. Pinkus, F. C. Pratt, V. I. Safro, E. A. Schwarz, J. S. Slack, G. D. Smith, H. S. Smith, C. S. Spooner, E. S. Tucker, G. N. Wolcott, and W. W. Yothers. Of these agents Dr. W. E. Hinds, who for several years was the principal assistant in the cotton boll weevil investigations of this bureau, was the most extensive contributor. To him we owe a large share of the accurate data on the life history and habits of the boll weevil. He also did a large amount of work in the preparation of Bulletin 51, upon which this publication is based. We have attempted throughout the bulletin to credit the various agents with the work for which they have been directly responsible, but in this place it must be stated that the results obtained are due to the faithful and efficient service of the whole corps of entomologists who have been associated with the writers. The work has also been greatly facilitated by the constant interest and encouragement of the chief of the bureau.

Special credit is due to Mr. E. S. Tucker for skillful preparation of the plates.

THE AUTHORS.

CONTENTS.

Page.

Origin and history 15
Distribution 20
Losses due to the boll weevil 21
Indirect losses caused by the boll weevil 26
Compensation for losses caused by the boll weevil 26
Prospects 27
Insects often mistaken for the boll weevil 29
Food plants of the boll weevil 31
Life history 32
- Summary 32

Description 33
- The egg 33
- The larva 33
- The pupa 34
- The adult 34
  - Before emergence 34
  - Description of adult 35
  - Size of weevils 35
  - Weight of weevils 35
  - Color of weevils 35
  - Secondary sexual characters 37

Seasonal history 38
- The adult weevil 38
  - Emergence 38
  - Changes after emergence 38
  - Protective habits 38
  - Food habits 38
    - Ability to locate cotton 41
    - Feeding habits of hibernated weevils 41
    - Destructive power by feeding 42
    - Attractiveness of various substances 42
    - Sense of color 43
    - Movements on food plant 43
    - Effects upon squares and bolls of feeding by the boll weevil 44
    - Susceptibility of various cottons 45
    - Duration of life of adult weevils 47
    - Cannibalism 50
  - Seasonal proportion of sexes 51
  - Fertilization 52
    - Age at beginning of copulation 52
    - Sexual attraction and duration of copulation 52
    - Duration of fertility 52
    - Parthenogenesis 53
  - Oviposition 53
    - Age at beginning of oviposition 53
    - Examination of squares before oviposition 54
    - Selection of uninfested squares for oviposition 54
    - Dependence of reproduction upon food obtained from squares 55
    - Place of egg deposition 56
    - The act of oviposition 56
    - Time required to deposit an egg 58
    - Stimulating effect of abundance of squares upon egg deposition 58
    - Activity of weevils in different parts of the day 58
    - Seasonal rate of oviposition 59
    - Is the fecundity of the weevil decreasing? 60
    - Period of oviposition 61
    - Effects of oviposition upon squares 61
    - Probable original breeding habit 62

Seasonal history—Continued.

Page.
The egg 62
  Duration of egg stage 62
  Hatching 64
  Hatching of eggs laid outside of cotton fruit 64
  Eating of eggs deposited outside 64
  Percentage of eggs that hatch 65
The larva 65
  Food habits 65
  Growth 65
  Molts 66
  Duration of larval stage 66
  Pupal cells 67
  Pupation 67
The pupa 67
  Activity 67
  Duration of pupal stage 67
Percentage of weevils developed from infested squares 68
Life cycle 69
  Duration of life cycle 69
    Sexual variations 69
    Variations due to location of developing stage 69
    Variations due to time of falling of infested squares 69
    Variations due to temperature 70
    Variations of development in bolls 72
    Miscellaneous variations 72
  Development of weevils in the squares which never fall 73
  Development during winter 73
Seasonal abundance 74
  Broods or generations 74
  Possible annual progeny of one pair of hibernated weevils 76
  Progress of infestation in fields 77
  Effect of maximum infestation upon weevil multiplication 79
  Status examinations 80
  Relation of weevils to top crop 81
  Variations in abundance of the weevil from year to year 83
Natural dissemination 85
  Spring search for cotton 85
  Spring spread within the field 86
  Summer flights 86
  Fall dispersion 87
  Hibernation flight 90
  Other forms of natural spread 90
Artificial dissemination 91
  Movement of seed cotton 91
  Movement of cotton seed 91
  Baled cotton 93
  Passing vehicles 93
  Movement of farm hands 93
  Unexplained sporadic occurrences 94
  Intentional transportation of the weevil 94
Hibernation 94
  Methods of study of hibernation 95
  Entrance into hibernation 96
    Sources of weevils entering hibernation 96
    Stages entering hibernation 96
    Time of entering hibernation 97
    Number of adult weevils entering hibernation 98
  Shelter during hibernation 100
  Activity during the hibernation period 103
  Duration of hibernation period 103
    Average length of hibernation period 103
    Relation of shelter to duration of hibernation 105
  Emergence from hibernation 107
    Time of emergence 107
    Rate of emergence 108
  Survival of hibernated weevils 110
    Relation of fall destruction to survival 111

Hibernation—Continued. Page.
  Survival of hibernated weevils—Continued.
    Relation of shelter to survival 112
    Relation of climate to survival 112
  Longevity of hibernated weevils 114
    Maximum length of life 115
  Relation of emergence and longevity to time of planting 116
  Nature of weevil activity following emergence from hibernation 116
Natural control 118
  Climatic control 120
    Climatic influences on vitality and activities 121
    Field observations on mortality due to heat and dryness 122
    General discussion of the relations of temperature to the boll weevil .. 125
      Upper zone of fatal temperature 126
      Zone of æstivation 127
      Zone of activity 127
      Zone of hibernation 127
      Lower zone of fatal temperatures 128
      Fatal variations of temperature 129
    Effects of flooding upon the weevil 131
  Plant control 132
    Proliferation 132
    Other phases of plant control 135
  Diseases 136
  Parasitic and predatory insect enemies 136
    A brief summary of the insect species attacking the boll weevil 136
  Birds 145
Repression 147
  Effect of burial of squares and weevils 147
    Laboratory experiments in burial 148
    Burial of adult weevils at time of hibernation 148
    Conclusions from burial experiments 148
  Insecticides 149
    Powdered arsenate of lead 150
  Machines 151
    Field machinery 151
    Ginning machinery 152
  Futile methods which have been suggested 153
    Mineral paint and cottonseed oil 153
    Spraying 153
    Sulphur 153
    Paris green 154
    Trapping at light 154
    Other proposed remedies 154
  Requirements of a satisfactory method of boll-weevil control 155
  Basis for means of repression 155
  Summary of means of repression of the boll weevil 160
  Destroying the boll weevil in cotton seed 162
  Legal restrictions regarding the boll weevil 164
    United States Statute 164
    Quarantines of the several States 164
Bibliography 169
Index 176

ILLUSTRATIONS.

PLATES.

Page.

Plate I. Cotton plant attacked by boll weevil. *a*, Hanging dry square infested by weevil larva; *b*, flared square with weevil punctures; *c*, cotton boll, sectioned, showing attacking weevil and weevil larva in its cell .... Frontispiece.

II. The boll weevil and insects often mistaken for it. *a*, The cotton boll weevil, *Anthonomus grandis; b*, the mallow weevil, *Anthonomus fulvus; c*, the southern pine weevil, *Pissodes nemorensis; d*, the cottonwood flower weevil, *Dorytomus mucidus; e, Conotrachelus erinaceus; f*, the pecan gall weevil, *Conotrachelus elegans* 28

III. Anatomical structure of the boll weevil. *a*, Dorsal view of anal segments of larva; *b*, front view of head and anterior segments of larva; *c*, ventral view of anal segments of larva; *d*, lateral view of adult; *e*, lateral view of larva; *f*, ventral view of adult; *g*, dorsal view of adult with wings spread; *h*, ventral view of pupa; *i*, ventral view of anal segments of pupa; *j*, ventral view of anterior portion of pupa 32

IV. The adult boll weevil and emergence holes. *a*. Squares of Peruvian cotton showing emergence holes of the Peruvian cotton square weevil; *b*, square of upland cotton showing emergence hole of the cotton boll weevil; *c*, adult boll weevil on cotton square; *d*, adult boll weevil puncturing cotton square; *e*, adult boll weevil emerging from cotton boll; *f*, small dry bolls showing emergence holes; *g*, hull of boll with weevils found hibernating 36

V. Effects of boll weevil attack on leaf and squares. *a*, Cotton leaf much fed upon by adults; *b*, square with two egg punctures; *c*, flared square with many feeding punctures; *d*, square prevented from blooming by puncture; *e*, bloom injured by feeding punctures; *f*, poor blooms caused by feeding punctures 40

VI. Injury by boll weevil to squares. *a*, Bloom checked by attacks of larva; *b*, square opened, showing grown larva; *c*, square opened, showing pupa; *d*, dwarfed boll opened, showing one larva and two pupæ; *e*, weevil escaping from square; *f*, emergence hole of adult in square 44

VII. Injury by boll weevil to bolls. *a*, Three larvæ in boll; *b*, emergence hole in dry, unopened boll; *c*, two larvæ in boll; *d*, weevils puncturing boll; *e*, opened boll with two locks injured by weevil; *f*, large bolls severely punctured 44

VIII. Field conditions in territory occupied by the boll weevil. *Fig. a.*—Newly planted cotton field, with sprouts from overwintered cotton roots. *Fig. b.*—Fallen infested squares 76

IX. Relation of boll weevil cells to seed. *a*, Boll weevil pupa found in cotton seed; *b*, boll weevil pupa in cell of lint from boll; *c*, weevil cell in dwarfed cotton boll containing live pupa taken among seed; *d*, weevil cells in bolls; *e*, cotton seeds 92

X. *Fig. a.*—Boll weevil remains after passing through fan from gin. *Fig. b.*—Ten-sectioned hibernation cage 96

XI. Hibernation conditions for the boll weevil. *Fig. a.*—Cotton field adjacent to timber covered with Spanish moss. *Fig. b.*—Proximity of moss-laden trees, conducing to high infestation by weevil.. 96

XII. Hibernation conditions for the boll weevil. *Fig. a.*—Standing dead timber and forest environment favorable for hibernation of weevils. *Fig. b.*—Litter in forest, suitable for hibernation of weevils 100

XIII. Hibernation conditions for the boll weevil. *Fig. a.*—Spanish moss on trees, very favorable for hibernation of weevils. *Fig. b.*—Density of Spanish moss as a protection to weevils in hibernation.. 100

Page.

PLATE XIV. Natural control of the boll weevil. *a*, Pilose and nonpilose stems of cotton; *b*, larva of boll weevil crushed by proliferation; *c*, pupa of *Catolaccus incertus* on pupa of cotton-boll weevil; *d*, larva of *Microbracon mellitor* attacking boll weevil larva; *e*, *f*, holes gnawed by *Solenopsis geminata* in effecting entrance into infested squares 120

XV. The difference between hanging and fallen squares. *Fig. a.*—Cotton squares with short absciss layer, permitting infested squares to fall. *Fig. b.*—Cotton squares with long absciss layer, retaining infested forms to hang and dry 136

XVI. Boll weevil ants. *a*, *Eciton commutatus; b*, *Cremastogaster lineolata; c*, *Dorymyrmex pyramicus; d*, *Monomorium pharaonis; e*, *Solenopsis molesta; f*, *Iridomyrmex analis* 140

XVII. Boll weevil parasites. *a*, *Eurytoma tylodermatis*, male; *b*, *Eurytoma tylodermatis*, female; *c*, *Microdontomerus anthonomi*, female; *c′*, antenna of same; *d*, *Habrocytus piercei*, female; *d′*, antenna of same; *e*, *Catolaccus hunteri*, female; *e′*, antenna of same; *f′*, antenna of *Catolaccus incertus* 140

XVIII. Boll weevil parasites. *a*, *Lariophagus texanus*, female; *b*, emergence hole of *Tetrastichus hunteri* from weevil larva; *c*, *Tetrastichus hunteri*, female; *c′*, antenna of same; *d*, puparium of *Ennyomma globosa* in weevil larva; *e*, *Ennyomma globosa; f*, *Cerambycobius cyaniceps*, female; *f′*, natural position of same .. 144

XIX. Effect of Paris green on cotton. *Fig. a.*—Cotton before treatment with Paris green. *Fig. b.*—Cotton one week after treatment with Paris green 148

XX. Cultural control of the boll weevil. *Fig. a.*—Early fall destruction of stalks, the fundamental method for controlling the boll weevil. Windrowing stalks for burning. *Fig. b.*—Chain cultivator passing through cotton rows 152

XXI. Use of chain cultivator. *Fig. a.*—Space between cotton rows before passage of cultivator. *Fig. b.*—Effect after passage of cultivator 152

XXII. Results of early and late planting of cotton. *Fig. a.*—Late-planted cotton under boll-weevil conditions, given same culture as early planting. *Fig. b.*—Early-planted cotton adjoining the late planting under same conditions 160

TEXT FIGURES.

1. Map showing the distribution of the cotton-boll weevil on January 1, 1912. 20
2. Map of portion of Texas, showing movement of the center of cotton production westward 25
3. Secondary sexual characters of *Anthonomus grandis* 37
4. Cotton-boll weevil: Head showing rostrum, with antennæ near middle and mandibles at end; mandible 39
5. Diagram showing average activity of five female boll weevils 59
6. Diagram to illustrate influence of temperature on average rate of oviposition of boll weevil 60
7. Diagram illustrating relationship of temperature to the egg period of the boll weevil at Victoria, Tex., in 1902 63
8. Diagram illustrating relationship of temperature to the egg period of the boll weevil and showing variations due to humidity 64
9. Diagram illustrating relationship of temperature to larval period of the boll weevil and showing range due to humidity 66
10. Diagram illustrating relationship between temperature and the pupal period of the boll weevil and showing variations due to humidity 67
11. Diagram illustrating effect of time of falling of infested squares upon period of development of boll weevil at Victoria, Tex., August, 1904 70
12. Diagram illustrating temperature control of developmental period of the boll weevil 71
13. Diagram illustrating normal developmental period of boll weevil in squares, by months, at Victoria, Tex., Ardmore, Okla., and Vicksburg, Miss. 71
14. Diagram illustrating seasonal history of the boll weevil at Victoria, Tex... 75
15. Status of the boll weevil in Texas in August, 1906; percentage of infestation of all forms 79

Page.
16. Status of the boll weevil in Texas in August, 1908; percentage of infestation of all forms.......... 80
17. Status of the boll weevil in Texas in August, 1909; percentage of infestation of all forms.......... 81
18. Status of the boll weevil in Texas in August, 1910; percentage of infestation of all forms.......... 82
19. Status of the boll weevil in Texas in August, 1911; percentage of infestation of all forms.......... 83
20. Curves of numerical strength of the boll weevil and its parasites.......... 84
21. The spread of the cotton-boll weevil from 1892 to 1911.......... 88
22. Diagram illustrating average length of hibernation period of the boll weevil as related to date of entering hibernation.......... 106
23. Diagram illustrating relations of effective temperature and precipitation to date of beginning emergence of the boll weevil.......... 107
24. Diagram illustrating average rate of emergence of the boll weevil from hibernation in Texas and Louisiana.......... 109
25. Diagram illustrating average longevity of boll weevils after emerging on a given date.......... 115
26. Diagram to illustrate the zones of temperature in their relations to the activities of the boll weevil.......... 126
27. Map showing dates of first killing frost in the area infested by the boll weevil, in the winter of 1909-10.......... 129
28. Map showing normal dates of first killing frost in the southern United States. 129
29. Map showing minimum temperatures on October 29 and 30, 1910, the date of the first killing frost in Louisiana.......... 130
30. Map showing minimum temperatures in the winter of 1910-11 in Louisiana. 130
31. *Evarthrus sodalis* an enemy of the boll weevil.......... 138
32. *Chauliognathus marginatus* an enemy of the boll weevil.......... 138
33. *Hydnocera pubescens* an enemy of the boll weevil.......... 139
34. Apparatus for fumigating cotton seed in the sack.......... 163

THE MEXICAN COTTON-BOLL WEEVIL: A SUMMARY OF THE INVESTIGATION OF THIS INSECT UP TO DECEMBER 31, 1911.

ORIGIN AND HISTORY.

There is very little certainty regarding the history of the Mexican cotton-boll weevil before its presence in Texas came to the attention of the Division of Entomology in 1894. The species was described by Boheman in 1843 from specimens received from Vera Cruz, and was recorded by Suffrian in 1871 as occurring at Cardenas and San Cristobal, in Cuba. Written documents in the archives at Monclova, in the State of Coahuila, Mexico, indicate that the cultivation of cotton was practically abandoned in the vicinity of that town about the year 1848, or at least that some insect caused very great fears that it would be necessary to abandon the cultivation of cotton. A rather careful investigation of the records makes it by no means clear that the insect was the boll weevil, although there is a rather firmly embedded popular opinion in Mexico, as well as in the southern United States, that the damage must have been perpetrated by that species. So far as the accounts indicate, it might have been the bollworm (*Heliothis obsoleta* Fab.) or the cotton caterpillar (*Alabama argillacea* Hübn.).

From the time of the note by Suffrian regarding the occurrence of the weevil in Cuba in 1871, up to 1885, there has been found no published record concerning it. In 1885, however, Dr. C. V. Riley, then Entomologist of the Department of Agriculture, published in the report of the Commissioner of Agriculture a very brief note to the effect that *Anthonomus grandis* had been reared in the department from dwarfed cotton bolls sent by the late Dr. Edward Palmer from northern Mexico.[1] This is the first account in which the species is associated with damage to cotton. The material referred to was collected in the State of Coahuila, presumably not far from the town of Monclova.

---

[1] The following is a copy of the original letter by Dr. Palmer:

EAGLE PASS, TEX., *Sept. 28, 1880.*

The COMMISSIONER OF AGRICULTURE.

SIR: Previous to leaving Monclova, Mexico, for this place I visited some fields planted with cotton. Seeing but few bolls of cotton, examination revealed the cause. An insect deposits its egg and the boll falls; thus some plants had only two or three, others five or six bolls, while underneath the leaves, in the shade thereof, were many that had fallen there in the moist shade to lay for the larva to hatch. Please find inclosed insects and many of the injured bolls, some newly punctured, others taken from under the plant.

Monclova, Mexico, and the surrounding country a few years ago was famous for its large supply of cotton; at this time none can be grown, owing to the destructive insect, samples of which are sent. The inhabitants would be glad to hear of a remedy, upon which matter in the future I will communicate with your department.

Your obedient servant,
EDWARD PALMER.

The specimens were sent by Dr. L. O. Howard to Mr. Henry Ulke, who transmitted them to Dr. George Horn, of Philadelphia. In turn Dr. Horn forwarded the material to Dr. Sallé, in Paris, who made the determination.

After the American occupation of Cuba the boll weevil began to attract considerable attention in that island. In 1902 it was observed that the weevil was quite injurious to cotton at Cayamas, Cuba. This place was visited by Mr. E. A. Schwarz, of the Bureau of Entomology, in the spring of 1903. He found that the native food plants of the weevil in Cuba were the "wild" or "loose" cotton (*Gossypium brasiliense*) and the native "kidney" cotton—both tree cottons.

The spread of the boll weevil in Mexico appears to have begun prior to 1892. In that year it appeared at Sabinas, State of Coahuila, and about this time or earlier it appeared at San Juan Allende, Morelos, Zaragoza, and Matamoras, Mexico. It crossed the Rio Grande at Brownsville probably before 1892. At any rate, during that year it caused considerable loss at Brownsville. In 1894 it had spread to half a dozen counties in the Brownsville region, and during the last months of the year was brought to the attention of the Division of Entomology as an important enemy of cotton. Mr. C. H. T. Townsend was immediately sent to the territory affected. His report, published in March, 1895, dealt with the life history and habits of the insect, which were previously entirely unknown, the probable method of its importation, and the damage that might result from its work, and closed with recommendations for fighting it and preventing its further advance in the cotton-producing regions of Texas. It is much to be regretted that at that time the State of Texas did not adopt the suggestion made by the Bureau of Entomology that a belt be established along the Rio Grande in which the cultivation of cotton should be prohibited, and thus the advance of the insect be cut off.[1] The events of the last few years have verified the predictions of the Division of Entomology in view of the advance made and the damage caused by the insect.

In 1895 the insect was found by the entomologists of the Division of Entomology, who continued the investigation started the year before, as far north as San Antonio and as far east as Wharton. Such a serious advance toward the cotton-producing region of the State caused the Bureau of Entomology to continue its investigations during practically the whole season. The results of this work were incorporated in a circular by Dr. L. O. Howard, published early in 1896, in both Spanish and English editions.

An unusual drought in the summer of 1896 prevented the maturity of the fall broods of the weevil, and consequently there was no extension of the territory affected. During 1896 the investigations were continued, and the results published in another circular issued in February, 1897. This circular was published in Spanish and German as well as English editions, for the benefit of the very large foreign population in southern Texas.

The season of 1897 was in many respects almost as unfavorable as that of 1896, but the pest increased its range to the region about Yoakum and Gonzales. Although this extension was small, it was exceedingly important, because the richest cotton lands in the United States were beginning to be invaded. The problem had thus become so important that Mr. C. H. T. Townsend was stationed in Mexico, in a region supposed to be the original home of the insect, for several months to discover, if possible, any parasites or diseases that might be affecting it, with the object of introducing them to prey upon the pest in Texas. Unfortunately, nothing was found that gave any hope of material assistance in the warfare against the weevil.

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[1] This suggestion was brought to the attention of the General Assembly of Texas by the then Assistant Secretary of Agriculture, Dr. C. W. Dabney, who went to Austin for that purpose.

The season of 1898 was very favorable for the insect. Investigations by the Bureau of Entomology were continued, and a summary of the work, dealing especially with experiments conducted by Mr. C. L. Marlatt in the spring of 1896, was published in still another circular. During this year the first of a long series of conventions to discuss the boll weevil was held. This meeting took place at Victoria, Tex., on October 12, and was attended by many planters, bankers, and merchants.

At this time the Legislature of the State of Texas made provision for the appointment of a State entomologist and provided a limited appropriation for an investigation of means of combating the boll weevil. In view of this fact the Bureau of Entomology discontinued temporarily the work that had been carried on through agents kept in the field almost constantly for four years, and all correspondence was referred to the State entomologist of Texas. Unfortunately, however, the insect continued to spread, and it soon became apparent that other States were threatened. This caused the work to be taken up anew by the Bureau of Entomology in 1901, in accordance with a special appropriation by Congress for an investigation independent of that which was being carried on by the State of Texas, and with special reference to the discovery, if possible, of means of preventing the insect from spreading into adjoining States.

In accordance with the provision mentioned the senior writer was sent to Texas in March, 1901, and remained in that State until December. He carried on cooperative work upon eight large plantations in the region infested by the weevil. The result of his observations was to suggest the advisability of a considerable enlargement of the scope of the work. It had been found that simple cooperative work with the planters was exceedingly unsatisfactory. The need of a means of testing the recommendations of the Bureau of Entomology upon a large scale, and thereby furnishing actual demonstrations to the planters, became apparent. Consequently, in 1902, at the suggestion of the Department of Agriculture, provision for the enlargement of the work was made by Congress. Agreements were made with two large planters in typical situations for testing the principal features of the cultural system of controlling the pest upon a large scale. At the same time the headquarters and laboratory of the special investigation were established at Victoria. The results of the field work for this year were published in the form of a Farmers' Bulletin. During this season cooperation was carried on with the Mexican commission charged with the investigation of the boll weevil in that country, which was arranged on the occasion of a personal visit of Dr. L. O. Howard to the City of Mexico in the fall of the preceding year. In November an enthusiastic convention of planters and merchants to discuss the problems was held at Dallas, Tex.

The favorable reception by the planters of Texas of the experimental field work conducted during 1902 and the increase in the territory occupied by the pest brought about an enlarged appropriation for the work of 1903. It thus became possible to increase the number and size of the experimental fields as well as to devote more attention to the investigation of matters suggested by previous work in the laboratory. Seven experimental and demonstrational farms, aggregating 558 acres, were accordingly established in as many distinct cotton districts in Texas.

During 1903 the weevil was recorded from San Juan, Guatemala, by G. C. Champion. In this same year it was discovered that the weevils were being introduced in cottonseed into the "Laguna" district in the State of Coahuila, Mexico, but effective measures were taken by the Mexican authorities, and the infestation was suppressed. Since that time the weevil has never been recorded from this important cotton region. The year 1903 is also important as being that in which the weevil first crossed the Sabine River into Sabine and Calcasieu Parishes in Louisiana. Another feature of the year was a large boll-weevil convention held at Dallas, Tex., which established a permanent organization and issued a number of valuable circulars relating to the problem. A similar meeting was held in New Orleans on November 30, at which the governor of the State presided.

In 1904 a general realization of the great damage done by the boll weevil led to the appropriation by Congress of $250,000 for use in enabling the Secretary of Agriculture to meet the emergency caused by the ravages of the insect. It thus became possible again to increase the number of experimental farms and to pay especial attention to a number of important matters that could not be investigated previously. The large appropriation was used in part to establish the demonstration work of the department. The object of this work was to demonstrate the methods of control perfected and demonstrated previously by the Bureau of Entomology. It has gradually developed into the well-known Farmers' Cooperative Demonstration Work of the Bureau of Plant Industry.

With the advent of the weevil into Louisiana that State began energetic work against the pest. Largely through the efforts of Prof. W. C. Stubbs an extraordinary session of the legislature was convened early in 1904. The action decided upon was the establishment of the Crop Pest Commission of Louisiana, with full authority to take such a course as might be found advisable. Prof. H. A. Morgan became secretary and entomologist of the commission. In 1905 Prof. Morgan was succeeded by Mr. Wilmon Newell, who continued the cooperative investigations with the Bureau of Entomology throughout the period of his services in Louisiana, which extended to January 31, 1910.

During 1904 two conventions were held at Shreveport, La. The first discussed especially the local features of the problem, while the second, which was held in November, was national in its scope. It was attended by delegates from most of the Southern States.

The year 1904 witnessed an extensive dispersion of the weevil into new regions in Texas and Louisiana. During this year, Dr. O. F. Cook, of the Bureau of Plant Industry, found the weevil thoroughly established in Alta Vera Paz, Guatemala.

At the beginning of 1905 the laboratory of the bureau was moved from Victoria to Dallas, Tex., where it has since remained. The observations on the activities of the boll weevil in this year were considerably limited, owing to restrictions on travel imposed by the yellow-fever quarantine. The insect was found, however, at Mazatlan, State of Sinaloa, on the Pacific coast of Mexico, on March 20, 1905.

In 1906 the weevil spread extensively to the west in Texas, a considerable distance northward into Oklahoma, into Arkansas, and almost to the Mississippi River in Louisiana. During this season Mr. M. T. Cook recorded the weevil from Santiago de las Vegas, Cuba, in addition to places previously recorded.

The year 1907 marked the crossing of the Mississippi River into the State of Mississippi. There was a corresponding movement to the north, but none to the west. A very severe setback, caused by climatic conditions, occurred in the northern and western parts of the infested territory in November, 1907.

In 1908 the most noticeable advances were made into Mississippi and Arkansas. By this time a considerable part of the Mississippi Delta region of Louisiana had become infested.

In the spring of 1909 preparations were made for the establishment of a laboratory at Tallulah, La. The main object of this laboratory has been the accumulation of data concerning the local features of the weevil problem in the region where the greatest damage is certain to occur. Cold weather in the winter of 1908–9 again checked the boll weevil so completely that it did no appreciable damage in Oklahoma and the greater part of Texas during 1909. The checking of the insect was enhanced by the very unusual heat of July and August. However, there were enough weevils in the Red River Valley to give rise to a considerable movement into Arkansas and to a remarkable eastward movement in southern Mississippi which ended with a total advance of 120 miles eastward. This carried the insect to within 6 miles of the Alabama border. At the same time the decided climatic control of the season held the weevils in check in northern Louisiana so that the total advance in the Delta was little more than 20 miles northeastward. The year 1909 closed with an exceptionally cold December which greatly reduced the numbers of the weevil in extreme northern Louisiana and in Arkansas, Oklahoma, and northern Texas.

The winter of 1909–10 was probably more disastrous for the weevil than any it had previously experienced in this country. It was shown by examinations made in June and July, 1910, that the weevil had lost a very wide belt of territory in western Texas and that there was less than 1 per cent infestation in one-third of the infested region of Oklahoma and Texas. The reduction was also very pronounced in northern Louisiana and in the Mississippi Delta. In August it was found that there had been some recovery of lost territory, but there were still several thousand square miles of formerly infested territory in Oklahoma which the weevil had been unable to regain. There were slight gains in western Texas in the vicinity of Abilene late in the season and rather pronounced gains in the Delta region of Arkansas and in the hills of northern Mississippi and eastward through southern Mississippi and Alabama to the border of Florida. On account of the general scarcity of weevils the total amount of damage done during 1910 was less than had been experienced for several preceding years.

An early frost on October 29, 1910, throughout all but the coast regions of the infested territory, caused the death of all but a very small fraction of the fall-bred weevils, and consequently the season of 1911 started with a low infestation. The general defoliation by the leaf worm, however, reduced the available food supply and caused a general dispersion, which enabled the weevils to regain considerable lost ground in Texas and Oklahoma, to make remarkable gains in Arkansas, Mississippi, and Alabama, and to invade Florida.

DISTRIBUTION.

The territory covered by the boll weevil at the end of the year 1911 (see fig. 1) included the southeastern half of the cotton section of Texas, the southeastern corner of Oklahoma, the southern three-fourths of Arkansas, all of Louisiana, the southern three-fourths of Mississippi, the southwestern corner of Alabama, and the western portion of Florida. In addition to these States the weevil is found throughout Mexico in the cotton-growing region of both the Atlantic and Pacific coasts with the exception of certain mountain regions. Foremost among the excepted regions is that known as the Laguna district in the vicinity of Torreon, Mexico. The weevil has not been recorded from any part of Yucatan excepting the western coast, although it may occur on tree cottons throughout this region. It has not been recorded from British Honduras, but is known to occur throughout the cotton regions of Guatemala and in Costa Rica. There is little doubt but that it also extends into other Central American Republics, although no definite records have ever been

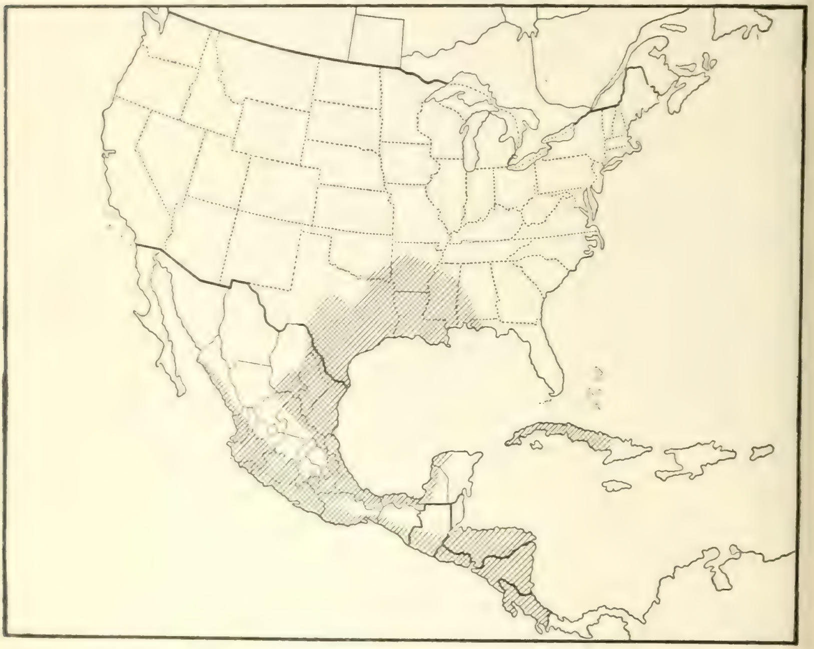

FIG. 1.—Map showing the distribution of the cotton-boll weevil on January 1, 1912. (Original.)

made. The five western States of Cuba are infested, and possibly the weevil is to be found throughout the entire island. It has not been found in any of the other West Indian Islands.

LOSSES DUE TO THE BOLL WEEVIL.[1]

Various estimates of the loss occasioned to cotton planters by the boll weevil have been made. In the nature of the case such estimates must be made upon data that are difficult to obtain and in the collection of which errors must inevitably occur. There is, of course, a general tendency to exaggerate agricultural losses as well as to attribute to a single factor damage that is the result of a combination of many influences. Before the advent of the boll weevil into Texas unfavorable weather at planting time, summer droughts, and heavy fall rains caused very light crops to be produced. Now, however, the tendency is everywhere to attribute all of the shortage to the weevil. Nevertheless, the pest is undoubtedly the most serious menace that the cotton planters of the South have ever been compelled to face, if not, indeed, the most serious danger that ever threatened any agricultural industry. It was generally considered, until the appearance of the pest in Texas, that there were no apparent difficulties to prevent an increase in cotton production that would keep up to the enlarging demand of the world until at least twice the present normal crop of about 12,000,000 bales should be produced. Now, however, in the opinion of most authorities, the weevil has made this possibility somewhat doubtful, although the first fears entertained in many localities that the cultivation of cotton would have to be abandoned have generally been given up. An especially unfavorable feature of the problem is in the fact that the weevil reached Texas at what would have been, from other considerations, the most critical time in the history of the production of the staple in the State. The natural fertility of the cotton lands had been so great that planters had neglected such matters as seed selection, varieties, fertilizers, and rotation, that must eventually receive consideration in any cotton-producing country. In general, the only seed used was from the crop of the preceding year, unselected, and of absolutely unknown variety, and the use of fertilizers had not been practiced at all. Although it is by no means true that the fertility of the soil had been exhausted, nevertheless, on many of the older plantations in Texas the continuous planting of cotton with a run-down condition of the seed combined to make a change necessary in order that the industry might be continued profitably.

In 1905 Prof. E. D. Sanderson[2] made a very careful estimate of the damage done by the boll weevil in Texas for the six years ending with 1904. During this period he found that there had been an average annual decrease due to the boll weevil of 43 per cent, amounting to 0.182 bale per acre a year in the infected territory.

Prof. Sanderson found that in 1899 the 18 counties infested at that time showed a decrease of 0.135 bale per acre, of which it was considered that 150,000 bales were chargeable to the weevil. In 1900 the great storm of September complicated matters so that no reliable estimate of injury could be made. In 1901 the general conditions throughout the State were unfavorable to the cotton crop, resulting in a reduction of 0.05 bale per acre for the uninfested portion of the State. The weevil loss was estimated at 100,920 bales. In 1902 the 32 counties infested produced 0.28 bale per acre. The loss chargeable to the boll weevil was 200,000 bales. In 1903 the 49 counties infested yielded 0.23 bale per acre, as against an average of 0.43 bale during years previous to infestation, which was interpreted to show a loss of 500,000 bales due to the weevil. In 1904, 69 counties were infested. These showed a loss of 0.22 bale per acre. This meant, after deducting the losses due to the bollworm and other causes, a loss of 550,000 bales due to the boll weevil. In these estimates the losses for the period from 1899 to 1904 amounted to 1,725,000 bales.

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[1] The following paragraph is modified from Bul. No. 51, Bureau of Entomology, pp. 21-25.

[2] The Boll Weevil and Cotton Crop of Texas, published by the Texas Department of Agriculture.

The weevil was in Texas from 1899 to 1904, but had not caused any appreciable damage in Louisiana during that period. The statistics of production and acreage of the two States for these years show clearly the effect of the weevil on the crop.

TABLE I.—*Comparison of cotton production and acreage in Texas and Louisiana in equivalents of 500-pound bales.*

Year.	Texas.		Louisiana.	
	Acreage.	Crop.	Acreage.	Crop.
	Acres.	*Bales.*	*Acres.*	*Bales.*
1899	6,642,309	2,609,018	1,179,156	700,352
1900	7,041,000	3,438,386	1,285,000	705,767
1901	7,745,100	2,502,166	1,400,650	840,476
1902	8,006,546	2,498,013	1,662,567	882,073
1903	8,129,300	2,471,081	1,709,200	824,965
1904	8,704,000	3,030,433	1,940,000	893,193

It will be seen that while the acreage in Texas and Louisiana increased at about the same proportion the crop in Texas decreased annually for the six years ending with 1904 (with two exceptions—1900 and 1904), while the crop in Louisiana increased annually (with one inconsiderable exception, in 1903). That the boll weevil prevented Texas from keeping pace with Louisiana during this period will be admitted by all. The exceptional years, 1900 and 1904, in which the production in Texas did not decrease, were those in which the conditions for the cotton plant were unusually favorable. Moreover, it is to be noted that in the first of these two years the pest had not reached far into the most productive counties.

Further indications of the amount of weevil damage are available from the statistics of production per acre, as shown by Table II:

TABLE II.—*Average yield per acre of cotton by five-year periods in 500-pound bales.*

Years.	Texas.	Louisiana.	Arkansas.	Oklahoma.	Mississippi.
	Bale.	*Bale.*	*Bale.*	*Bale.*	*Bale.*
1879	0.39	0.58	0.58	0.48	0.45
1889	.37	.51	.40	.48	.40
1893–1897	[1] .38	.52	.45	.52	.43
1898–1902	[1] .39	.52	.45	.47	.40
1903–1907	[1] .34	[1] .49	[1] .40	[1] .47	.44
1908–1910	[1] .32	[1] .29	[1] .37	[1] .35	[1] .40

[1] During these periods the weevil has caused more or less damage to the crop.

At 13 cents a pound for lint (average price in 1909) the 1908–1910 average yields would mean an average loss from the average yield of 1893–1897 of the following amounts per acre:

Texas	$3.90
Louisiana	15.25
Arkansas	5.20
Oklahoma	11.05
Mississippi	1.95

Messrs. Norden & Co., of New York, have made a conservative estimate of the average annual loss in the various States, as follows:

	Per cent.
Texas, about	15
Louisiana	15
Arkansas	15
Mississippi	21

The Bureau of Statistics of this department estimated the losses to the cotton crop in 1909 from various causes as shown below:[1]

TABLE III.—*Amount of injury to cotton crop of 1909 due to various causes.*

State.	Loss in seed cotton per acre from—						
	Climatic conditions.	Boll weevil.	Boll-worm.	Other insects.	Plant diseases.	Miscellaneous causes.	Total.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Arkansas	112.2	21.5	2.5	0.7	14.4	0.7	152.0
Louisiana	38.8	148.8	8.5	1.3	11.0	1.4	209.8
Mississippi	103.3	14.1	8.0	0.7	18.8	3.1	148.0
Oklahoma	147.3	11.0	3.7	0.4	2.2	3.4	168.0
Texas	100.4	37.6	8.7	0.0	7.7	0.6	155.0
Average of infested region	100.4	46.6	6.2	0.6	10.8	1.8	166.4

According to this estimate, the boll weevil was responsible for 28 per cent of the loss in the five infested States and 14.9 per cent of the loss in the United States. This loss was estimated as 1,267,000 bales of 500 pounds, which, at the current price of cotton in 1909, would be worth $88,056,500. Although the estimate of the Bureau of Statistics may be high, it was based upon the reports of numerous trained observers throughout the infested territory.

Frequently misconceptions arise regarding the manner in which the weevil has affected cotton production in Texas. This is due to the fact that the total crop of the State has been maintained more or less regularly since the advent of the pest. In order to obtain exact information on this point we must examine the statistics of production in different parts of the State.[2]

It is necessary to divide the State into three areas. These are eastern, central, and western Texas. The divisions are made in accordance with variations in normal annual precipitation and other factors. Eastern Texas as used in this bulletin is bounded on the west by a line running practically north and south from the western line of Lamar County to the western line of Brazoria County. In this region the rainfall is 45 inches per year or more. It comprises the counties listed below.[1] Practically the whole area is covered with forests. It covers 40,180 square miles. Central Texas comprises a broad belt from the Gulf to the Red River, beginning on the west with the limit of the belt of 32 inches normal annual rainfall, and extends eastward to the line just described as defining the western boundary of the eastern Texas area. Central Texas consists of 45 counties[2] and comprises 38,868 square miles.

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[1] Crop Reporter, vol. 12, No. 12, p. 94, December, 1910.

[2] The following four paragraphs and table are extracted, with a few modifications, from Circular No. 122, Bureau of Entomology, pp. 5–8.

It is for the most part prairie country, although there are wooded valleys and occasional strips of timbered uplands. Western Texas comprises the remainder of Texas, beginning with the line marking the western limit of the area of 32 inches normal annual precipitation. It is largely a prairie region, though wooded valleys are numerous. Another factor in differentiating western Texas from central Texas is the increased elevation.

A careful study has been made of the manner in which the weevil has affected the production of cotton in the three regions mentioned. Use has been made of the Census records of production from 1899 to 1910, a period of 12 years, as shown in Table IV:

TABLE IV.—*Eastern, central, and western Texas cotton production compared, 1899–1910 from United States Census.*

[500-pound bales.]

Years.	Eastern.		Central.		Western.[3]	
	Bales.	Proportion of Texas crop.	Bales.	Proportion of Texas crop.	Bales.	Proportion of Texas crop.
		Per cent.		*Per cent.*		*Per cent.*
1899	637,872	22.44	1,633,618	62.61	337,528	12.94
1900	811,413	23.59	1,892,669	55.04	734,304	21.36
1901	633,620	25.32	1,448,872	57.90	419,674	16.77
1902	736,660	29.48	1,332,487	53.34	428,866	17.17
1903	545,288	22.06	1,242,654	50.28	683,139	27.64
Average, 1899–1903	672,970	24.88	1,510,060	55.85	520,702	19.26
1904	720,671	22.91	1,700,224	54.15	724,475	23.07
1905	329,523	12.96	1,414,115	55.63	798,294	31.40
1906	672,497	16.11	2,213,863	53.03	1,287,846	30.85
1907	343,328	14.92	1,218,143	52.95	738,708	32.11
1908	515,038	13.50	1,980,766	50.60	1,318,681	33.68
1909	474,311	18.80	1,362,096	53.99	686,404	27.20
1910	645,158	21.15	1,677,688	55.02	726,553	23.83
Average, 1904–1910	528,647	17.19	1,652,414	53.62	797,280	28.88

In eastern Texas the production for five years ending with 1903 averaged 24 per cent of the total crop of Texas. During the same series of five years western Texas averaged 19 per cent of the total crop. For the seven years ending with 1910 the eastern Texas production dropped to 17 per cent of the total crop of the State, while the production in western Texas advanced to 28 per cent of the total crop of the State. In other words, the portion of the Texas crop produced in one area has decreased 21 per cent, and in the other it has increased 53 per cent. This increase in the west, where the dry climate reduces the boll-weevil injury, served to offset the loss in eastern Texas and thus accounts to a great extent for the fact that the total crop of the State has not fallen off.

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[1] Red River, Bowie, Franklin, Titus, Morris, Cass, Wood, Camp, Upshur, Marion, Harrison, Smith, Gregg, Cherokee, Rusk, Panola, Nacogdoches, Shelby, San Augustine, Sabine, Angelina, Trinity, San Jacinto, Polk, Tyler, Jasper, Newton, Liberty, Hardin, Orange, Jefferson, Chambers Galveston, Lamar, Delta, Hopkins, Rains, Van Zandt, Henderson, Freestone, Anderson, Leon, Houston, Madison, Waller, Grimes, Walker, Montgomery, Harris, Fort Bend, and Brazoria.

[2] Central Texas counties: Cooke, Grayson, Fannin, Denton, Collin, Hunt, Tarrant, Dallas, Rockwall, Kaufman, Johnson, Ellis, Bosque, Hill, Navarro, McLennan, Limestone, Bell, Falls, Williamson, Milam, Robertson, Brazos, Travis, Lee, Burleson, Washington, Hays, Bastrop, Caldwell, Fayette, Colorado, Austin, Guadalupe, Gonzales, Lavaca, Wharton, Dewitt, Goliad, Victoria, Jackson, Refugio, Calhoun, Matagorda and Aransas.

[3] Including counties grouped by Census under "All other."

Mr. F. W. Gist, of the Bureau of Statistics of this department, has made a very careful study to determine the center of cotton production in Texas for each year from 1899 to 1908. As would be supposed from the figures that have been given, it was found by Mr. Gist that the center of production had moved considerably to the westward. In fact, this center moved from 30.78 miles east of the ninety-seventh meridian in 1899 to 19.14 miles west of this meridian in 1908. This was a westward movement of practically 50 miles. The center of production in 1899 was on a line passing north and south through the eastern portion of Grayson county, in Texas. In 1908 the center had moved to a line passing parallel with the other through the western portion of Cooke County, in Texas. These statements may be illustrated by the following map (fig. 2).

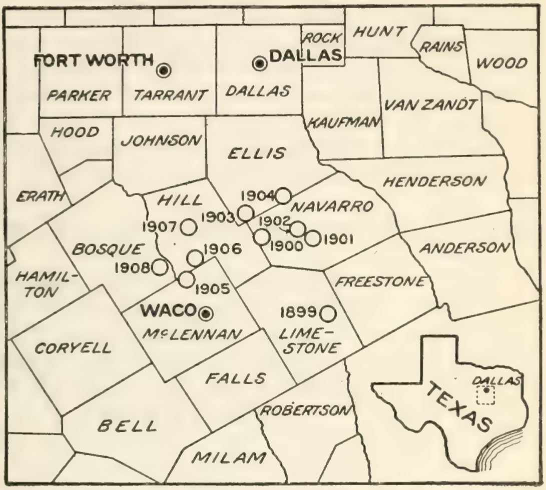


FIG. 2.—Map of portion of Texas, showing movement of the center of cotton production westward. (Original.)

The statistics which have been given show the entire fallacy of attempting to estimate the seriousness of the boll-weevil problem by considering only the total crop which has been produced in Texas for some years past. It is absolutely necessary in estimating the damage that is likely to be done in any certain region to find the portion of Texas in which the climatic and other conditions are most like those in the region that is being considered. In Texas there are several very distinct boll-weevil problems due to local conditions, exactly as there are numbers of distinct agricultural provinces. The future of the boll weevil in the eastern part of the United States can not be foretold unless the manner in which the insect has affected the portion of Texas which is most like the eastern part of the belt is considered. An investigation of this matter will show that the eastern part of Texas is the only part of the State which is like the eastern portion of the cotton belt in the climatic and other features which react upon the boll weevil. This is especially the case with reference to precipitation, the presence of timber, and temperature. It is clear, therefore, that the only criterion by which to judge the future damage of the weevil is the effect it has exerted on production in eastern Texas, where, as has been shown, there has been a considerable decrease in production.

INDIRECT LOSSES CAUSED BY THE BOLL WEEVIL.

The foregoing discussion has dealt altogether with the direct losses caused by the boll weevil, but it is to be noted that there are certain indirect losses which must be considered. It is not alone the farmers who are affected. The reduction in the size of the cotton crop immediately affects the ginning and oil-mill industries in which large amounts of money are invested. The railroads, banks, and merchants are also concerned. In fact, the disturbance extends throughout the community. In the case of many parishes in Louisiana one of the first results of the invasion of the boll weevil has been the reduction in the assessed valuation of farm lands. In all regions, for at least a short time, the price of farm properties has been reduced. Likewise in many localities the invasion of the insect has caused the exodus of large numbers of tenants and even of landlords. In the former case landowners have found themselves without the labor to run their places. Losses due to such disturbances can not be estimated, but it is safe to say that they reach an aggregate amount at least equal to the direct losses which are caused.

COMPENSATIONS FOR LOSSES CAUSED BY THE BOLL WEEVIL.

In spite of the great losses caused by the boll weevil it must be recognized that certain compensations are returned. The insect forces a diversification of crops. There is no doubt that there is a tendency to place too much dependence in the South upon the cotton crop. When the ravages of the boll weevil reduce the size of this crop materially or make production of a cotton crop hazardous, the farmers must change their system of cropping materially. This results directly in diversification and animal husbandry, and thus tends toward a more logical and profitable system of agriculture. Of course it would be much better if this change could be brought about by less revolutionary means and with less loss than is caused by the boll weevil. The tendency for many years has been toward diversification, which was certain to come in time. The boll weevil has undoubtedly hastened it and has thus in a broad sense offset, to a certain degree, some of the direct losses which it has caused. It is to be noted, however, that in many cases this forced and, in one sense, premature diversification of crops has resulted disastrously. In some localities extensive and rapid growth has taken place in fruit raising and market gardening. In some of these instances the new industries have developed with abnormal rapidity and without the proper foundation. This was the case in extensive plantings of potatoes made in 1909 by the cotton planters of Avoyelles Parish, La. The result has been that unless carefully managed the new lines of farming have failed and there has been a tendency to return to the cultivation of cotton.

The boll weevil also tends to eliminate the indifferent and unprogressive farmer. He is driven either to the city or to some other locality.

In this way the weevil works toward the production of a better class of farmers. Of course, no community favors a reduction in the number of inhabitants. It would prefer that the inefficient remain and be improved by education or otherwise. This effect of the invasion of the boll weevil, therefore, can not generally be looked upon as a benefit.

PROSPECTS.

The rapid spread of the boll weevil in the past few years and its apparent adaptability to most of the conditions prevalent in the cotton region of the United States indicate that it will ultimately be able to exist in all except the semiarid portions of the entire cotton-growing country. In order better to estimate the probable movement in the future, we present Table V to illustrate its progress since the year 1892:

TABLE V.—*Annual movement of the boll weevil in the United States.*

Year.	Weevil advance.							Total movement.	Total area infested.
	Texas.	Louisiana.	Oklahoma.	Arkansas.	Mississippi.	Alabama.	Florida.		
	Sq. mi.	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*	*Sq. mi.*
1892	1,400							1,400	1,400
1893	7,400							7,400	8,800
1894	10,300							10,300	19,100
1895	7,900							7,900	27,000
1896	[1]7,300							[1]7,300	19,700
1897	9,600							9,600	29,300
1898	7,200							7,200	36,500
1899	6,600							6,600	43,100
1900	6,600							6,600	49,700
1901	6,700							6,700	56,400
1902	11,600							11,600	68,000
1903	11,700	300						12,000	80,000
1904	39,600	7,300						46,900	126,900
1905	17,000	3,400						20,400	147,300
1906	22,600	9,300	4,200	500				36,600	183,900
1907		5,000	8,200	7,800	500			21,500	205,400
1908		5,700	1,500	6,500	4,800			18,500	223,900
1909		9,800	1,900	7,500	10,700			29,900	253,800
1910	1,400		[1]6,500	1,900	13,500	3,900		14,200	268,000
1911	[1]21,000		[1]3,000	9,700	11,000	5,400	1,400	3,500	271,500
Total	139,300	40,800	6,300	31,900	40,500	9,300	1,400	271,500	

[1] These figures indicate losses instead of gains.

A summary of Table V in three-year periods is given below:

TABLE VI.—*Average annual rate of boll-weevil movement.*

Three-year periods.	Total movement.	Yearly average.	Average of averages.
	Sq. miles.	*Sq. miles.*	*Sq. miles.*
1892–1894	19,100	6,366	
1895–1897	10,200	3,400	
1898–1900	20,400	6,800	5,522
1901–1903	30,300	10,100	
1904–1906	103,900	34,633	
1907–1909	69,900	23,300	22,677
	253,800		14,099

At the end of 1910 the total area infested was 268,000 square miles, a net gain of 14,200 square miles over 1909. Including the year 1910, the average rate of movement in the United States beginning with

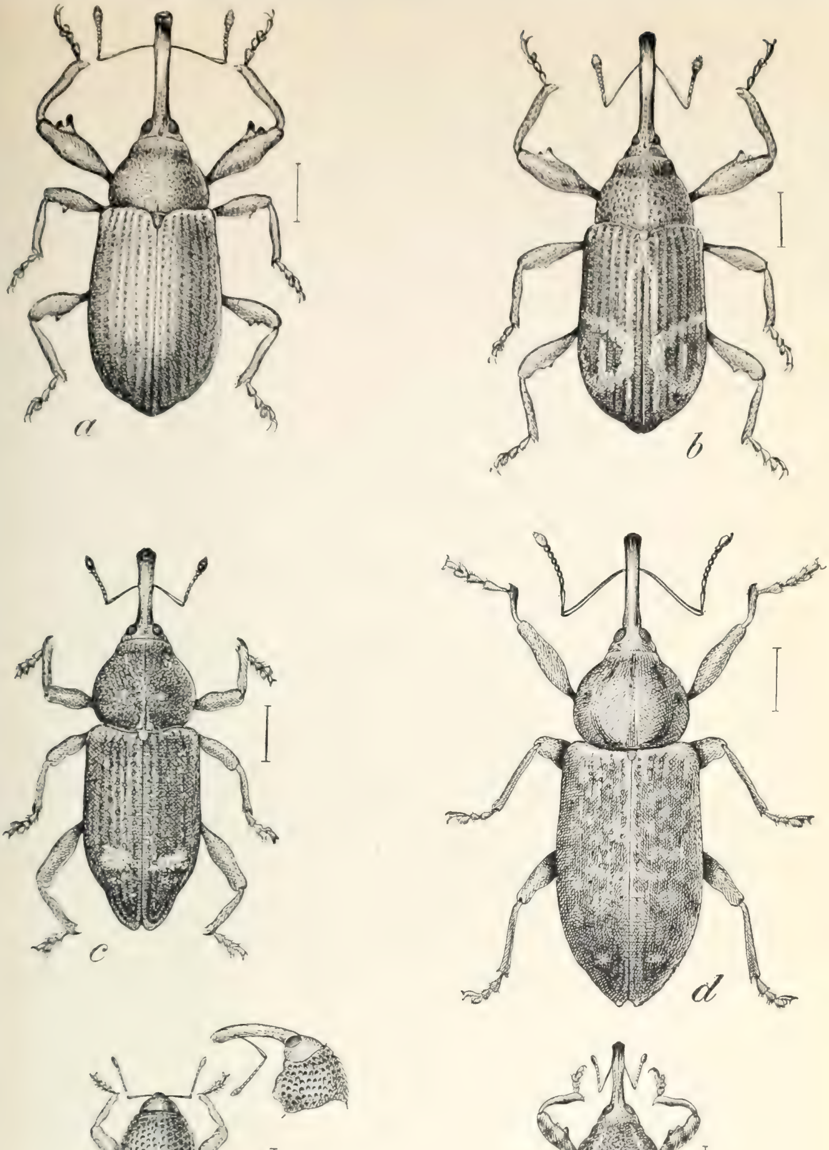
1904 has been 27,000 square miles a year, with 402,000 square miles of cotton-producing area yet free. It is therefore reasonable to estimate that it will take at least 15 years before the entire cotton region of this country can become infested.

It is evident, however, that the weevil will find certain definite checks in the cotton-growing regions of this country. Among the more important of these checks are (1) dryness, (2) low winter temperatures, (3) altitude, and (4) such combinations of these factors as tend to form definite life zones. The possible effects of these factors will be discussed separately.

Dryness is the most important check the boll weevil experiences. The insect has repeatedly advanced into western Texas, but has invariably been prevented from gaining a foothold by the dry climate of that region. Occasional wet seasons have resulted in apparent gains in that quarter, but they have been nullified by the recurrence of normal years. The extremely dry conditions in Texas, Oklahoma, and Arkansas during the summers of 1909 and 1910 had a remarkable effect upon the weevil. Combined with the very severe winters, these dry summers practically excluded the weevils from the western half of the infested region of Texas and most of the infested region in Oklahoma. The damage done in these regions for two seasons has occurred only after the breaking of the intense summer heat. The occasional occurrence of a dry summer, however, does not give any promise of future immunity from the boll weevil, because its tendency to disperse in the fall in all directions enables it to regain any ground which it might lose during such a season. It is also important to note that the practice of irrigation in dry regions may counteract the effects of the lack of precipitation and enable the weevil not only to maintain itself, but to cause considerable damage.

The low temperatures of the winters of 1907, 1908, and 1909 had a very pronounced effect upon the numbers of the weevil in the following years. An analysis of the minimum temperatures reached in the regions where the weevils were most affected indicates that such control was the result of a temperature of 12° above zero. In some places where this temperature was reached there were earlier low temperatures which may have forced the weevils into considerably heavier shelter than they would have selected normally. This apparently enabled the weevils to survive even a temperature of 5° above zero. Although the information at hand is rather incomplete, we can nevertheless hold out some hope that regions having a minimum temperature of from 5° to 10° above zero will have little trouble from the boll weevil. In later sections of this bulletin we will show how even higher minimum temperatures can greatly reduce the weevil damage of the following year. The weakness of predictions of this kind is that they do not take into account the fact that the weevil is rapidly adjusting itself to changed conditions and that eventually the result of natural selection will be a class of weevils which can withstand greater vicissitudes than those of the present.

The extremely slow progress into western Texas might be explained on the basis of altitudes. So far, the weevil has not established itself at an altitude above 2,000 feet. It may be possible that this altitude is its extreme limit. Again, there is danger in this assumption.



THE BOLL WEEVIL AND INSECTS OFTEN MISTAKEN FOR IT

a, The cotton boll weevil, *Anthonomus grandis*; *b*, the mallow weevil, *Anthonomus fulvus*; *c*, the southern pine weevil, *Pissodes nemorensis*; *d*, the cottonwood-flower weevil, *Dorytomus mucidus*; *e*, *Conotrachelus erinaceus*; *f*, the pecan gall weevil, *Conotrachelus elegans*. (Original.)

because the boll weevil has shown considerable adaptability in the past and may be able to adapt itself to higher altitudes than it has yet reached.

With regard to the possible relation between life zones and the distribution of the weevil it is to be said that at present the infested territory includes the tropical regions of Cuba, Central America, and Texas, and a considerable part of the Austroriparian Zone of the Lower Austral Region in the other Southern States. It is interesting to note that the weevil has not yet succeeded in establishing itself in the Upper Sonoran Zone of the Upper Austral Region of either Mexico or western Texas. It has invaded, or at least surrounded, two isolated areas of the Carolinian Zone of the Upper Austral Region in Oklahoma and Arkansas. Considerable cotton is grown in western Texas, in the Upper Sonoran Zone. There also exist in Arkansas, southern Missouri, Tennessee, northern Georgia, northern South Carolina, western North Carolina, and Virginia large regions of cotton-producing territory included in the Carolinian Zone. It is possible that the boll weevil will be unable to establish itself permanently beyond the limits of the Lower Austral Zone and this would exclude it from the regions just mentioned.

As a matter of fact, the effects of climatic conditions upon the weevil are so powerful that there may be occasional diminution in the serious attacks from the insect in the moist regions, such as was experienced in the summer of 1911. The season of 1911 was unusual in Louisiana and Mississippi, starting with severe cold in January, which cut down the emergence from hibernation to 0.5 per cent, and continuing with a very unusual drought. Such conditions are not often experienced, and we may usually expect severe attack by the weevil in southern Louisiana and the Delta of Mississippi.

INSECTS OFTEN MISTAKEN FOR THE BOLL WEEVIL.

The anticipated appearance of a serious pest such as the boll weevil in new regions causes greater attention to be given to the insects found in the cotton fields. Many planters notice common native insects which appear to answer the description of the boll weevil. The result of such mistaken identifications is generally a local panic. On account of the difficulty of distinguishing the boll weevil from a large number of related insects, we advise that whenever a planter discovers an insect which he suspects to be the boll weevil he send it either to the State entomologist or to the Bureau of Entomology and receive authoritative information.[1]

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[1] Addresses of officials who will give authentic determinations of the boll weevil:
Alabama.—W. E. Hinds, Auburn.
Arkansas.—Paul Hayhurst, Fayetteville.
Florida.—E. W. Berger, Gainesville.
Georgia.—E. L. Worsham, Atlanta.
Louisiana.—J. B. Garrett, Baton Rouge.
Mississippi.—R. W. Harned, Agricultural College.
North Carolina.—Franklin Sherman, jr., Raleigh.
Oklahoma.—C. E. Sanborn, Stillwater.
South Carolina.—A. F. Conradi, Clemson College.
Tennessee.—G. M. Bentley, Knoxville.
Texas.—Wilmon Newell, College Station. Ernest Scholl, Austin, Department of Agriculture. W. D. Hunter, Bureau of Entomology, Dallas.
Virginia.—E. A. Back, Blacksburg.

Many of the weeds in the vicinity of the cotton fields are attacked by different species of weevils which may in some respects resemble the boll weevil. Some of these weevils are of a general dark color and have beaks with which to puncture their food plants. On close observation it will be found that the weevils which are discovered on other weeds are breeding in those weeds. They are not the boll weevils and will not attack the cotton. Many of these native weevils are also found on the cotton plants at the nectar which is produced by the squares, blooms, and leaves. These weevils simply visit the cotton plants in order to feed upon this nectar and do not injure the plant in any way. The following list contains the names and references to the habits of some of the most common weevils which occur in and about cotton fields:

Insects often mistaken for the boll weevil (*Anthonomus grandis* Boh.). (Pl. II, *a*.)

Weevil.	Attacks.
Anthonomus albopilosus Dietz	Seed pods of wild sage (Croton).
Anthonomus eugenii Cano	Pepper pods.
Anthonomus fulvus Le C. (Pl. II, *b*)	Purple mallow buds.
Anthonomus signatus Say	Blackberry, dewberry, and strawberry buds.
Anthribus cornutus Say	Cotton stems.
Araecerus fasciculatus DeG	China-berries, coffee beans, and old cotton bolls.
Balaninus nasicus Say	Acorns.
Balaninus victoriensis Chitt	Live oak acorns.
Baris striata Say	Roots of ragweed (Ambrosia).
Baris transversa Say	Roots of cockle-bur (Xanthium).
Chalcodermus æneus Boh	Cowpea pods.
Conotrachelus elegans Say (Pl. II, *f*)	Galls and nuts of pecans.
Conotrachelus erinaceus (Pl. II, *e*)	Habits unknown.
Conotrachelus leucophæatus Fab	Stems of careless weed (Euphorbia).
Conotrachelus naso LeC	Acorns.
Conotrachelus nenuphar Hbst	Fruit of plums and peaches.
Desmoris constrictus Say	Seed of sunflower (Helianthus).
Desmoris scapalis LeC	Flower heads of broad-leaved gum plant (Sideranthus).
Dorytomus mucidus Le C. (Pl. II, *d*)	Cottonwood catkins.
Epicærus imbricatus Say	Habits unknown, adult feeds on foliage.
Geræus penicellus Hbst	Habits unknown, visits cotton nectar.
Geræus picumnus Hbst	Habits unknown, visits cotton nectar.
Gerstæckeria nobilis LeC	Joints of prickly pear.
Hylobius pales Hbst	Pine bark.
Lixus scrobicollis Boh	Stems of ragweed (Ambrosia).
Pachylobius picivorus Germ	Pine branches and bark.
Pissodes nemorensis Germ. (Pl. II, *c*)	Pine branches and bark.
Rhynchites mexicanus Gyll	Rosebuds.
Rhyssematus palmacollis Say	Morning-glory pods.
Trichobaris mucorea LeC	Tobacco stalks.
Trichobaris texana LeC	Spanish thistle stalks. (*Solanum rostratum*).
Tychius sordidus LeC	Pods of false indigo (Baptisia).

Many other insects are sometimes mistaken for the boll weevil. This list includes only the species which are more or lesss closely allied to that insect and consequently more commonly confused with it.

FOOD PLANTS OF THE BOLL WEEVIL.[1]

The careful investigations of Mr. E. A. Schwarz in Guatemala, Mexico, and Cuba have convinced him that the original food plants of the boll weevil are the tree cottons of those countries. One of these species has the seeds adhering together in a mass and is called "kidney" cotton from the shape of this mass. The other has seeds separated as in Upland cotton of the United States and is probably the *Gossypium brasiliense* of botanists. The former appears to be the more ancient form and presumably is the species upon which the weevil originally subsisted. Cotton is now rarely cultivated in Cuba, but the practically wild tree cottons are found throughout the island, and on these the boll weevil is generally to be found, although in very small numbers. There are, however, frequently found throughout the island isolated plants which are not infested. The areas of cultivation of cotton in Guatemala are extremely isolated, but the presence of tree cotton perpetuates the weevil and gives it a rather general distribution. In Mexico the principal regions of cotton growth are represented by narrow belts along the two coasts and a large area in the north-central portion known as the "Laguna." Tree cotton probably serves to continue the boll weevil's activity in many parts of Mexico where cotton is not cultivated. It is impossible to decide whether the boll weevil originated in Cuba or in Central America, as it occurs in practically the same condition in both places. It is, however, practically certain that the insect has attacked the cotton plant from antiquity. In fact, there is nothing to indicate that it ever had any other food plant.

The question of the possibility that the boll weevil may feed upon some plant other than cotton is one of importance. As an illustration we may state that as long as cotton is extensively produced in any given region there is comparatively little danger, but if a certain region should forego the planting of cotton for a period of years in order to escape boll-weevil injury and then resume its cultivation, it is apparent that all efforts would fail if the boll weevil could in the meanwhile exist on other native plants.

It is a well-known fact that insects which have few food plants usually confine their attacks to closely related plants belonging to the same botanical family or even genus. The native plants most closely allied to cotton in the regions so far infested are the various species of Hibiscus and the trailing mallows of the genus Callirrhoe. Careful tests have been made with these plants and with many unrelated plants, both as to their powers of sustaining life and the inducements offered for oviposition. Six species of Hibiscus, namely, *esculentus*, *vesicarius*, *manihot*, *moscheutos*, *militaris*, and *africanus*, have been tested to ascertain how long the weevil could live on them and whether it would oviposit in the fruit. In experiments conducted by Dr. W. E. Hinds hibernated weevils starved in an average time of about four days with leaves of either *Hibiscus esculentus* or *H. militaris*. Weevils of the first generation which had fed upon no cotton were placed upon *Hibiscus militaris*, and these starved within an average of three or four days. The first-generation weevils which had fed for a few days on squares were placed upon leaves, buds, and seed pods of *Hibiscus vesicarius*. Though they fed a little, all starved in an average of about five days. A lot of first-generation weevils, fed first for several days with squares, were given leaves, buds, and seed pods of okra. More feeding was done by this lot than by any other, all parts being slightly attacked. These weevils lived for an average of seven days. In experiments conducted independently by Messrs. Tucker and Jones at Alexandria and Shreveport, La., and Dallas, Tex., with *H. moschuetos*, *H. militaris*, and *H. africanus*, weevils were found to feed slightly on the pods, and fertile eggs were also found on the outside of the pods, but none were ever placed within.

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[1] There has recently been discovered by Prof. C. H. T. Townsend another serious cotton pest, *Anthonomus vestitus* Boheman, which we may designate as the Peruvian cotton square weevil, as it is not at present known outside of Peru and Ecuador. Prof. C. S. Banks has also discovered in the Philippine Islands a weevil feeding in cotton flowers which may be known as the Philippine cotton flower weevil. This species has been described as *Ecthetopyga gossypii* Pierce. The coffee-bean weevil, *Aræcerus fasciculatus* DeGeer, frequently breeds in old dried cotton bolls, and the cowpea pod weevil, *Chalcodermus æneus* Boheman, breeds occasionally in fresh cotton squares in fields of cotton following cowpeas. On account of the existence of these other square and boll weevils it is still necessary to retain the original name Mexican cotton boll weevil for *Anthonomus grandis* Boheman.

No results whatever were obtained by experiments with a species of Abutilon. In an experiment with hollyhock (*Althæa* sp.) three weevils lived an average of six days. In experiments by Mr. W. W. Yothers with buds of *Callirrhoe involucrata*, 42 weevils were fed for an average of 5.6 days, the maximum length of life being 11 days. These records show that the weevils may possibly be able to feed for a few days on some of the other malvaceous plants and that they may even be forced to oviposit, but that under present conditions they are unable to sustain life or to reproduce in these plants. The maximum length of life which they have been able to live on any of these plants is hardly greater than they could live with sweetened water (see Table XIII).

Unsuccessful attempts were made to cause the weevil to feed upon sunflower (*Helianthus annuus*), bindweed (*Convolvulus repens*), the pigweeds (*Amaranthus hybridus* and *A. spinosus*), the ragweed (*Ambrosia psilostachya*), and various other species of weeds and grasses which occur more or less frequently around cotton fields.

Throughout the investigations of Prof. C. H. T. Townsend in southern Texas and Mexico and of Mr. E. A. Schwarz in Texas, Cuba, Mexico, and Guatemala, and the observations made by the writers and their associates in all the infested region of the United States, every plant closely related to cotton has been most carefully watched. The uniform failure to find the weevil feeding upon any other plant makes it practically certain that cotton is its only food plant. Of course, the insect sometimes alights upon other plants, as it does upon fence posts and other objects. Such occurrences are altogether accidental. Frequent reports of the finding of the weevil breeding in other plants are due to mistaking some other insect for the enemy of cotton.

LIFE HISTORY.

SUMMARY.[1]

The egg is deposited by the female weevil in a cavity formed by eating into a cotton square or boll. The egg hatches in a few days and the footless grub begins to feed, making a larger place for itself as it grows. During the course of its growth the larva sheds its skin at least three times, the third molt being at the formation of the pupa, which after a few days sheds its skin, whereupon the transformation

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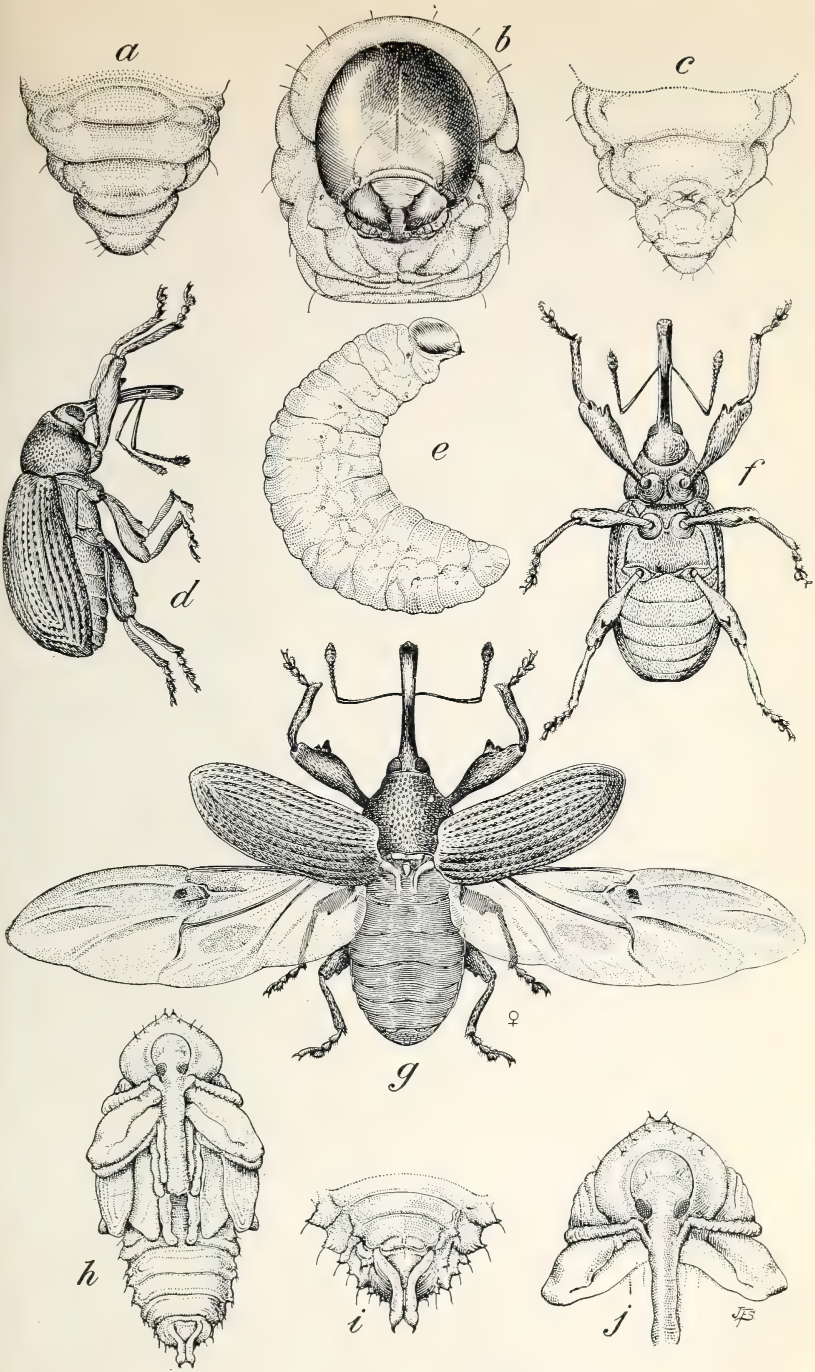
[1] Extract from Bulletin 51, Bureau of Entomology, pp. 30, 31.



ANATOMICAL STRUCTURE OF THE BOLL WEEVIL.

a, Dorsal view of anal segments of larva; *b*, front view of head and anterior segments of larva; *c*, ventral view of anal segments of larva; *d*, lateral view of adult; *e*, lateral view of larva; *f*, ventral view of adult; *g*, dorsal view of adult with wings spread; *h*, ventral view of pupa; *i*, ventral view of anal segments of pupa; *j*, ventral view of anterior portion of pupa. (Original.)

becomes completed. These immature stages require on the average between two and three weeks. A further period of feeding equal to about one-third of the preceding developmental period is required to perfect sexual maturity so that reproduction may begin.

DESCRIPTION.

THE EGG.[1]

The egg of the boll weevil is an unfamiliar object even to many who are thoroughly familiar with the succeeding stages of the insect. If laid upon the exterior of either square or boll, it would be fairly conspicuous on account of its pearly white color. Measurements show that it is, on the average, about 0.8 mm. long by 0.5 mm. wide. Its form is regularly elliptical, but both form and size vary somewhat. Some eggs are considerably longer and more slender than the average, while others are ovoid in shape. The shape may be influenced by varying conditions of pressure in deposition and the shape of the cavity in which it is placed. The soft and delicate membrane forming the outer covering of the egg shows no noticeable markings, but is quite tough and allows a considerable change in form. Were the eggs deposited externally they would doubtless prove attractive to some egg parasite as well as to many predatory insect enemies. Furthermore, the density of the membranes would be insufficient to protect the egg from rapid drying or the effects of sudden changes in temperature. All these dangers the female weevil avoids by placing the eggs deeply within the tissue of the squares or bolls upon which she feeds. As a rule, the cavities which receive eggs are especially prepared therefor and not primarily for obtaining food. Buried among the immature anthers of a square or on the inner side of one carpel of a boll, as they frequently are, weevil eggs become very inconspicuous objects and are found only after careful search.

THE LARVA.[2]

(Pl. III, *a*, *b*, *c*, *e*.)

The young larva, upon hatching from the egg, is a delicate, white, legless grub of about 1 mm. ($\frac{1}{25}$ inch) in length. Except for the brown head and dark brown mandibles the young larva is at first as inconspicuous as the egg from which it came. As it feeds and grows it continues to enlarge a place for itself in the square or boll until the food supply has become exhausted or the vegetable tissues are so changed as to be unsuitable for food. By this time, as a rule, the interior of the square has been almost entirely consumed and the larval castings are spread thickly over the walls of the cavity. This layer becomes firmly compacted by the frequent turning of the larva as it nears the end of this stage. In the cell thus formed occur the marked changes from the legless grub to the fully formed and perfect beetle.

Throughout this stage the body of the larva preserves a ventrally curved, crescentic form. The color is white, modified somewhat by the dark color of the body contents, which show through the thinner, almost transparent portions of the body wall. The dorsum is strongly wrinkled or corrugated, while the venter is quite smooth. The ridges on the dorsum appear to be formed largely of fatty tissue. After becoming full grown the larva ceases to feed, the alimentary canal becomes emptied, and both the color and form of the larva are slightly changed. The dark color disappears from the interior and is replaced by a creamy tint from the transforming tissues within. The ventral area becomes flattened, and the general curve of the body is less marked. Swellings may be seen on the sides of the thoracic region, and when these are very noticeable pupation will soon take place.

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[1] Extract from Bulletin 51, Bureau of Entomology, p. 31.
[2] Extract from Bulletin 51, Bureau of Entomology, pp. 34, 35.

THE PUPA.[1]

(Pl. III, *h*, *i*, *j*.)

When the pupal stage is first entered the insect is a very delicate object both in appearance and in reality. Its color is either pearly or creamy white. The sheaths for the adult appendages are fully formed at the beginning of the stage, and no subsequent changes are apparent except in color. The eyes first become black, then the proboscis, elytra, and femora become brownish and darker than the other parts. The pupa of the boll weevil can be distinguished readily from any other pupa which might be found in a cotton square or boll. Like all other curculionid pupæ, its beak rests on the venter of the body, with the legs drawn up at the sides and with the elytra on the dorsum as they will appear in the adult. But the boll-weevil pupa has two large quadrate tubercles on the prothorax, practically at the anterior apex of the body, and the abdominal segment which serves as the apex is produced in a rather chitinous flattened process, which is inflated at the middle and deeply quadrately emarginate at apex, leaving only two strong acute teeth projecting.

The final molt requires about 30 minutes. The skin splits open over the front of the head and slips down along the proboscis and back over the prothorax. The skin clings to the antennæ and the tip of the proboscis until after the dorsum has been uncovered and the legs kicked free. Then by violently pulling upon the skin with the forelegs the weevil frees first the tip of the snout and then the antennæ, and finally with the hind legs it kicks the shrunken and crumpled old skin off the tip of the abdomen.

THE ADULT.

(Pl. II, *a;* Pl. III, *d*, *f*, *g*.)

BEFORE EMERGENCE.

Immediately after its transformation from the pupa the adult is very light in color and comparatively soft and helpless. The proboscis is darkest in color, being of a yellowish brown; the pronotum, tibiæ, and tips of the elytra come next in depth of coloring. The elytra are pale yellowish, as are also the femora. The mouth parts, claws, and the teeth upon the inner side of the fore femora are nearly black. The body is soft, and the young adult is unable to travel, consequently this period is passed where pupation occurs. Usually two or more days are required to attain the normal coloring and the necessary degree of hardness to enable the adult to make its escape from the square or cell.[1] This is known as the teneral adult stage.

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[1] Modified and expanded from Bulletin 51, Bureau of Entomology, p. 38.

DESCRIPTION OF ADULT.

The following technical description of the species is taken from the Revision of Genera and Species of Anthonomini Inhabiting North America, by Dietz.[2]

Anthonomus grandis Boh.—Stout, subovate, rufo-piceous and clothed with coarse, pale-yellowish pubescence. Beak long, slender, shining, and sparsely pubescent at the base; striate from base to the middle, striæ rather coarsely punctured; apical half finely and remotely punctured. Antennæ slender, second joint of funicle longer than the third; joints 3–7 equal in length, but becoming gradually wider. Head conical, pubescent, coarsely but remotely punctured, front foveate. Eyes moderately convex, posterior margin not free. Prothorax one-half wider than long; base feebly bisinuate, posterior angles rectangular; sides almost straight from base to middle, strongly rounded in front; apex constricted and transversely impressed behind the anterior margin; surface moderately convex, densely and subconfluently punctured; punctures irregular in size, coarser about the sides; pubescence more dense along the median line and on the sides. Elytra oblong, scarcely wider at the base than the prothorax; sides subparallel for two-thirds their length, thence gradually narrowed to and separately rounded at the apex, leaving the pygidium moderately exposed; striæ deep, punctures large and approximate; interstices convex, rugulose, pubescence somewhat condensed in spots. Legs rather stout, femora clavate, anterior strongly bidentate, inner tooth long and strong, outer one acutely triangular and connected with the former at the base; middle and posterior thighs unidentate. Tibiæ moderately stout, anterior bisinuate internally, posterior straight; tarsi moderate, claws broad, blackish, and rather widely separate; tooth almost as long as claw. Long. 5–5.5 mm.; 0.20–0.22 inch.

SIZE OF WEEVILS.

The size of boll weevils is somewhat variable. It varies almost directly in proportion to the abundance of the larval food supply and the length of the period of larval development. It also depends upon the nature of the food, whether it is squares or bolls.[3] The smallest weevils are developed from squares which are very small, and which, for some reason, either of plant condition or of additional weevil injury, fall very soon after the egg is deposited. In such cases the supply of food is not only small, but possibly, owing to the immaturity of the pollen sacs, its quality is poor. Normally, squares continue to grow for a week or more after eggs are deposited in them, and such squares produce the weevils of average size and color.

The largest weevils are produced in bolls which grow to maturity. In them the food supply is most abundant, and the period of larval development is several times as long as it is in squares. Weevils reared from squares late in the season, where infestation has reached its maximum, are of small size, whereas weevils reared from large bolls are very noticeably larger. The extremes are so great that the largest and smallest weevils would be thought, by one not familiar with them, to be of entirely different species. So far as dimensions may convey an idea of the size, we may say that the weevils range from 2.5 mm. to 6.75 mm. ($\frac{1}{10}$ to $\frac{1}{4}$ inch) in length, measuring from base of beak to apex of elytra, and from 1 mm. to 3 mm. ($\frac{1}{25}$ to $\frac{1}{8}$ inch) in breadth at the middle of the body.

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[1] The foregoing is extracted from Bulletin 51, Bureau of Entomology, p. 39.
[2] Trans. Amer. Ent. Soc., vol. 18, p. 205.
[3] The following sentences are taken from Bulletin 51, Bureau of Entomology, p. 41.

WEIGHT OF WEEVILS.

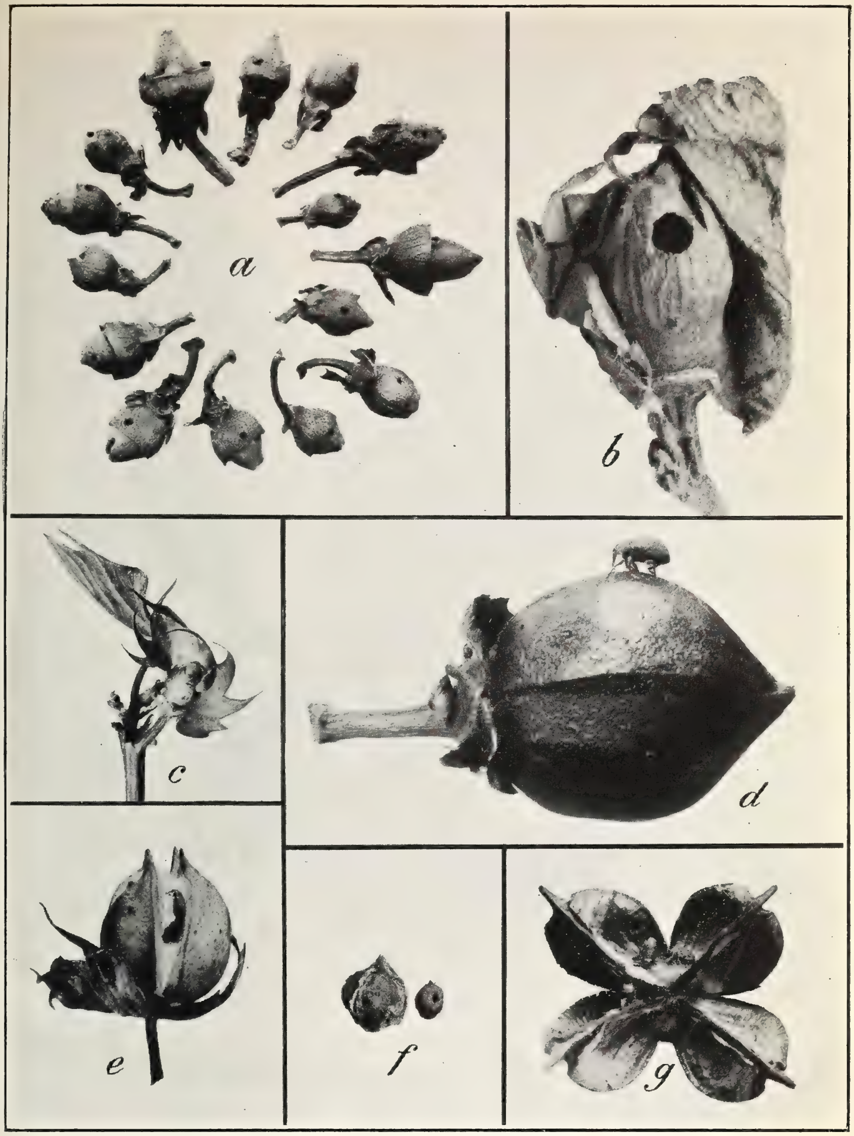
A number of interesting observations have been made at various times upon the weight of weevils in connection with the nature of the food supply. These observations have been tabulated, as follows:

TABLE VII.—*Weight of boll weevils from different sources.*

Source.	Condition when weighed.	Number.	Average weight.
			Grains.
Picked small squares	Fed	25	0.105
Average fallen squares	do	68	.231
Do	Unfed	36	.102
Do	Fed	9	.110
Fallen squares	do	15	.080
Large bolls	do	69	.268
Total		222	
Average			.192

COLOR OF WEEVIL.

Color is very often a variable character in insects, and the boll weevil presents considerable range in this respect. Normally, the general color becomes darker with age. Consequently, hibernated weevils are the darkest found, but another factor must be considered. As has been noted, whatever influences the size of the larva affects directly the size of the adult, and it is noticeable that weevils of the same size are also, as a rule, similar in color. In general, the smaller the size of the weevil, the darker brown is its color; the largest weevils are light yellowish brown. Between these two extremes are the majority of average-sized weevils, which are either of a gray-brown or dark yellow-brown color. In the opinion of Dr. W. E. Hinds the principal reason for the variation in color lies in the degree of development of the minute, hair-like scales, which are much more prominently developed in the large than in the small specimens, although the color of old specimens is often changed by the abrasion of the scales. These scales are yellow in color, while the ground color of the chitin bearing them is a dark brown or reddish brown. The development of the scales appears to take place mostly after the adult weevils have become quite dark in color, but before the chitin becomes fully hardened. They seem, therefore, to be, to a certain extent, an aftergrowth which depends upon the surplus food supply remaining after the development of the essential parts of the weevil structure.



THE ADULT BOLL WEEVIL AND EMERGENCE HOLES.

a, Squares of Peruvian cotton, showing emergence holes of the Peruvian cotton-square weevil; *b*, square of upland cotton, showing emergence hole of the cotton-boll weevil; *c*, adult boll weevil on cotton square; *d*, adult boll weevil puncturing cotton square; *e*, adult boll weevil emerging from cotton boll; *f*, small dry bolls, showing emergence holes; *g*, hull of boll, with weevils found hibernating. (Original.)

SECONDARY SEXUAL CHARACTERS.[1]

We are indebted to Dr. A. D. Hopkins, of the Bureau of Entomology for indicating the most strongly marked points of difference in the secondary sexual characters of the boll weevil. (See fig. 3.) The distinctive characters are found upon the snout and upon the last two abdominal segments. The differences are subject to some variation, but are still sufficiently constant to enable a close observer with the aid of a hand lens positively to differentiate males from females.

Female.—The snout of the female is slightly longer and more slender than that of the male. When viewed from above it usually appears to taper slightly from each end toward the middle. The antennæ are inserted slightly farther from the tip than is the case in the male. The insertion is at about two-fifths of the distance from the tip of the snout to the eyes. As a rule the surface of the snout is more smooth and shining than in the male. A slight depression, rather elongated and much larger than any of the other punctures upon the snout, occurs between the bases of the antennæ. When the wing covers and wings are unfolded the abdomen shows seven distinct dorsal segments. The last segment visible in the female, called the propygidium, can be seen only from the sides.

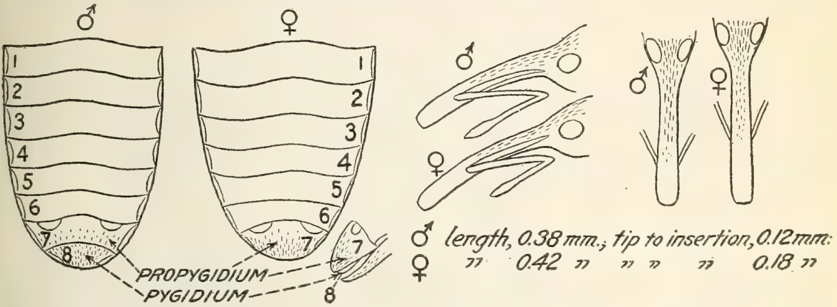


FIG. 3.—Secondary sexual characters of *Anthonomus grandis*. (From Hinds and Yothers, after Hopkins.)

Male.—In the male the snout is slightly shorter, thicker, and more coarsely punctured than in the female. The depression mentioned in the female is lacking. The antennæ are inserted at practically one-third of the distance from the tip of the snout to the eyes. The sides of the snout are very nearly parallel. In the abdomen the male shows eight distinct dorsal segments, the terminal segment (pygidium) not being covered by the propygidium as is the case in the female.

In general practice an examination of the beak is sufficient to determine the sex of each weevil.

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[1] This discussion is modified from Bull. 77, Bureau of Entomology, pp. 91, 92.

SEASONAL HISTORY.

THE ADULT WEEVIL.

EMERGENCE.[1]

(Pl. IV, *b*, *e*; Pl. VI, *e*, *f*.)

The adult boll weevil's normal method of escape from squares and small bolls is by cutting with its mandibles a hole just the size of its body. In large bolls the escape of the weevil is greatly facilitated by the natural opening of the boll. Often the pupal cell is broken open by the spreading of the carpels, and when this is the case the pupa, if it has not already transformed, becomes exposed to the attack of enemies or, what is probably a more serious menace, to the danger of drying so as seriously to interfere with a successful transformation. If the cell remains unbroken the weevil always escapes by the path of least resistance, cutting its way through as in the case of a square.

CHANGES AFTER EMERGENCE.[2]

At the time of emergence the weevils are comparatively soft, and they do not attain their final degree of hardness for some time after they have begun to feed. The chitin is of an orange tinge at the time the weevils leave the squares or bolls, but after exposure for some time it turns to a dark chocolate brown.

PROTECTIVE HABITS.

Not only is the boll weevil protected from its enemies by its color, which resembles both the dry squares and also the pulverized soil upon which it frequently drops, but it has a protective habit, found more or less commonly among insects. At the first disturbance of the cotton plant, or sometimes even at a movement of a large object in the vicinity of the cotton plant, the boll weevil becomes very alert, raising its antennæ and standing almost motionless. If the disturbance continues, the weevil falls to the ground with its legs drawn up close to the body and the antennæ retracted against the beak, which is brought inward toward the legs. In this position it often remains motionless for some time, but if further disturbed, it will start up quickly, run a short distance and again fall over, feigning death. This habit is popularly known as "sulling"[3] or "playing possum." Frequently, in falling, the weevil comes in contact with some part of the plant and immediately relaxes and takes shelter on the plant, or sometimes it spreads its wings and flies away instead of falling to the ground. In July and August the weevils become more alert than at any other season of the year, and flight more frequently follows the dropping from the plants.

FOOD HABITS.

Before escaping from the square the adult empties its alimentary canal of the white material remaining therein after the transformation. The material removed in making an exit from the cell is not used as food, but is cast aside. Weevils are ready to begin feeding very soon after they escape from the squares or bolls in which the previous stages have been passed. For several days thereafter both sexes feed almost continuously. They much prefer squares, but in confinement will feed upon leaves, flowers, or bolls. Under natural conditions any portions of the plants other than the squares and bolls are seldom attacked. The bolls are only slightly attacked so long as there is an abundance of uninfested squares.

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[1] Extracted from Bull. 51, Bureau of Entomology, pp. 39, 40.
[2] Extracted from Bull. 51, Bureau of Entomology, p. 40.
[3] Undoubtedly a corruption of "sulking."

[1] The method of feeding is alike in both sexes. The mouth parts are very flexibly attached at the tip of the snout (fig. 4) and are capable of a wide range of movement. The head fits smoothly into the prothorax like the ball into a socket joint and is capable of a considerable angle of rotation. The proboscis itself is used as a lever in prying, and helps to enlarge the puncture through the floral envelopes especially. Feeding is accomplished by a combination of movements. The sharply toothed mandibles serve to cut and tear, while the rotation of the head gives the cutting parts an auger-like action. The forelegs especially take a very firm hold upon the square and help to bring a strong pressure to bear upon the proboscis during certain portions of the excavating process. The outer layer of the square, the calyx of the flower, is naturally the toughest portion that the weevil has to penetrate, and only enough is here removed to admit the snout. After that is pierced the puncture proceeds quite rapidly, combinations of chiseling, boring, and prying movements being used. While the material removed from the cavity is used for food, the bulk of the feeding is upon the tender, closely compacted, and highly nutritious anthers or pollen sacs of the square. When these are reached the cavity is enlarged, and as much is eaten as the weevil can reach. The form of the entire puncture becomes finally like that of a miniature flask.

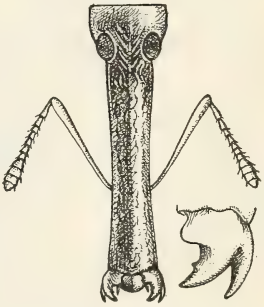

Fig. 4.—Cotton-boll weevil: Head, much enlarged, showing rostrum, with antennæ near middle and mandibles at end; mandible, more enlarged, at right. (Original.)

Only after weevils have fed considerably do sexual differences in feeding habits begin to appear; from this time on the females puncture mainly the base and the males the tip of the square.

Feeding punctures are much larger and deeper than are those made especially for the reception of the eggs; more material is removed from the inside of the square or boll and the opening to the cavity is never intentionally closed. Feeding punctures are most frequently made through the thinner portion of the corolla not covered by the calyx. The exposed tissue around the cavity quickly dries and turns brown from the starting of decay. As a number of these large cavities are often formed in one square (Pl. V, *c*), the injury becomes so great as to cause the square to flare immediately, often before the weevil has ceased to feed upon it. Squares so severely injured fall in a very short time. The injury caused by a single feeding puncture is often overcome by the square, which continues its normal course of development. When feeding punctures are made in squares which are nearly ready to bloom, the injury commonly produces a distorted bloom (Pl. V, *e, f*), and in very severe cases the boll will drop soon after setting.

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[1] The following four paragraphs are borrowed from Bulletin 51, Bureau of Entomology, pp. 50, 51.

After the females begin to oviposit their feeding habits become quite different from those of the males. Up to this time both sexes move but little, making a number of punctures in a single square; but from this point we must consider the feeding habits of the sexes separately.

Males puncture the tip portion of the square not covered by the calyx more often than do the females. The yellow or orange colored excrement is abundant, and owing to the somewhat sedentary habits of the males it accumulates often in rather large masses, so that it is often possible to tell whether a square in the field has been attacked by a male rather than by a female weevil. Observations made by Dr. Hinds on 70 specimens under both field and laboratory conditions show that for the first few days of their life the males make from six to nine punctures a day, but that during their entire life they average about 1.2 punctures per day and an average of 2.6 punctures per square, injuring only about two squares every three days. Whether in or out of doors, the activity of feeding decreases as the male becomes older.

After they begin to oviposit females seem generally to feed less upon one square or in one puncture than they do previous to that time. They obtain quite a considerable portion of their food from the excavations which they make for the deposition of their eggs, and as they show a strong inclination to oviposit only in clean or previously uninfested squares their wandering in search of such squares keeps their punctures scattered so long as plenty of clean squares can be found. When clean squares become scarce, the normal inclination can not be followed, and the number of punctures made in each square will be greatly increased.

Table VIII is presented to illustrate the feeding activity of both sexes:

TABLE VIII.—*Rate of making egg and feeding punctures by the boll weevil.*[1]

Character of lot.	Number of males.	Number of females.	Total.			Average.		
			Weevil days.	Feeding punctures.	Egg punctures.	Feeding punctures per weevil day.	Egg punctures per female day.	Period of observation.
								Days.
Hibernated weevils in laboratory	55	54	4,938	17,406	5,702	+3.5	+2.3	+45.3
Weevils of first generation in laboratory	31	27	3,258	16,487	3,565	+5.0	−2.4	−56.2
Hibernated females in field cage	....	4	93	284	489	+3.0	−5.3	−23.3
First-generation females in field cage	....	5	70	263	435	−3.8	+6.2	14.0
Males in laboratory	65	....	2,492	5,617	....	−2.3	....	+38.3
Males in field	5	....	145	177	....	1.2	....	+29.0
Total	156	90	10.996	40,234	10,191	....	....	....
Average	....	....	....	....	....	3.6	2.4	44.7

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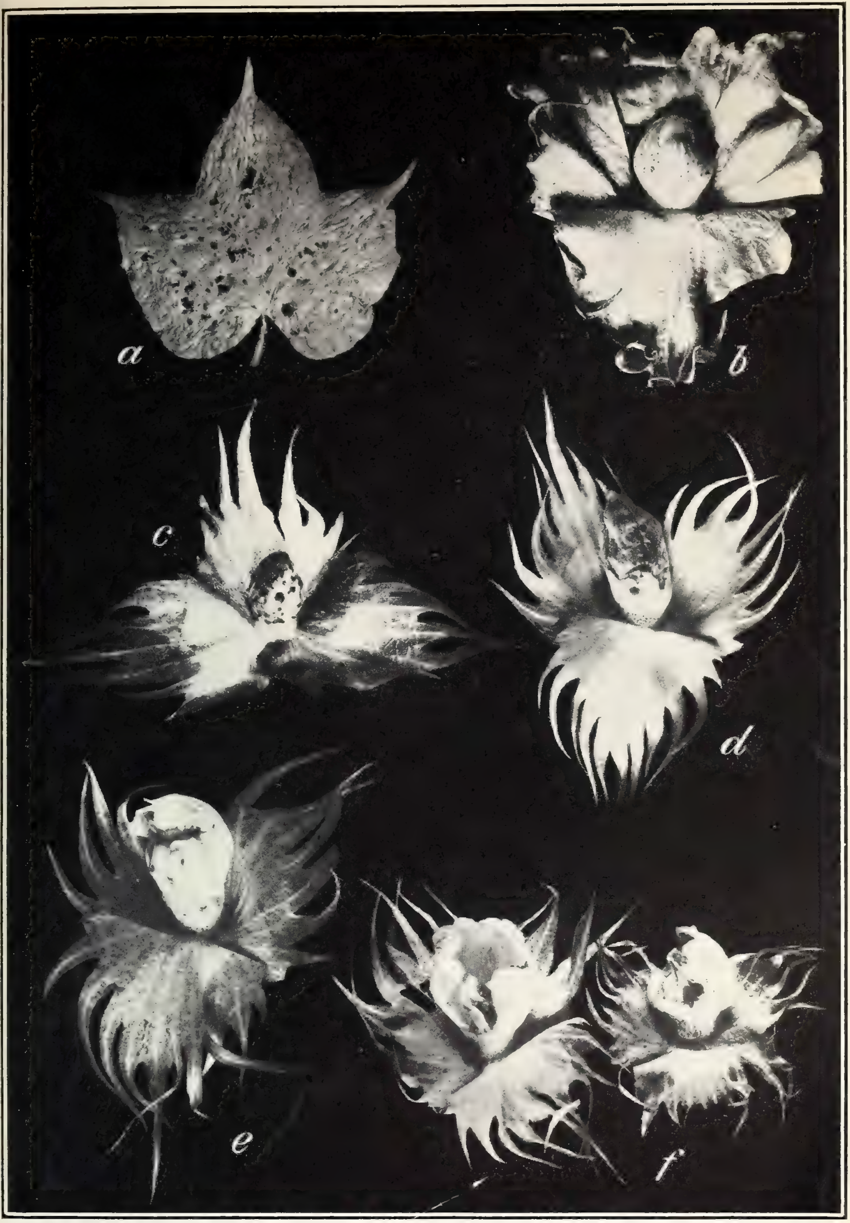
[1] Modified from Bulletin 51, Bureau of Entomology, p. 52.



EFFECTS OF BOLL-WEEVIL ATTACK ON LEAF AND SQUARES.

a, Cotton leaf much fed upon by adults; *b*, square with two egg punctures; *c*, flared square with many feeding punctures; *d*, square prevented from blooming by puncture; *e*, bloom injured by feeding punctures; *f*, poor blooms caused by feeding punctures. (Original.)

ABILITY TO LOCATE COTTON.

When hibernated weevils emerge from their winter quarters in search of food they are frequently long distances from the nearest cotton field. It has been a question of considerable interest whether the weevils are able to locate cotton or whether they find it by chance. Dr. A. W. Morrill conducted a series of experiments in the laboratory to test the attraction of cotton squares for the weevil, but the results were not conclusive. In the eight years of study of the boll weevil, there have been very few records of weevils on any other plants than cotton, notwithstanding the fact that special collections were made in the woods and fields near the cotton fields in search of boll weevils. In the season of 1905 extensive collections were made by means of sweeping nets by several men for weeks during the dispersion season, and yet not a single weevil was found outside of the cotton fields. All of this would indicate that there is some attraction of the weevils to cotton. The concentration of weevils upon the earliest plants in the spring and upon the greenest and most luxuriant portions of the fields in the fall are also evidences of the ability of the weevils to find desirable places for feeding.

FEEDING HABITS OF HIBERNATED WEEVILS.

Whether there be few or many hibernated weevils makes no difference in their feeding habits. The stage of the cotton at the date of emergence determines largely the nature of the food habits at that time. The first weevils to emerge obtain their food from the tender, rapidly growing, terminal portions of the young plants. They place themselves upon the node where the two cotyledons branch. In fact, this seems to be the point usually attacked in cases of very young cotton plants. In almost all cases the puncture of the weevil at this point results in the death of the plant. Sometimes the attack is made a little above the node on a petiole of the cotyledon, in which case the one cotyledon falls and the other remains, and the plant usually recovers. However, it frequently happens that the same weevil attacks both of the cotyledons. This form of attack is fatal to the seedlings unless they have become very vigorous—sometimes until they have developed two true leaves. Later the central bud, young leaves, or tender stems are attacked, and upon these the weevils easily subsist until the squares are developed. (See Pl. V, *a*.) In cases where the emergence from hibernation is very large the weevils may come out in such numbers upon the newly sprouted cotton as to stunt or even kill the growing plants by their depredations upon the terminal portion.

Weevils which have fed upon tender tips of plants seem perfectly satisfied with their food supply, and it appears that their first meal upon squares is largely the result of accident. After having begun to feed upon squares, however, it appears that their taste becomes so fixed that they normally seek for squares.

In the spring of 1895 Mr. E. A. Schwarz found the first emerged hibernated weevils working upon plants which had sprung from 2-year-old roots. In the spring of 1903 in one field of comparatively early cotton, 2 or 3 acres in extent, the senior author found, between April 24 and May 11, 23 weevils working on the buds and tender leaves of stubble plants before a single weevil was found on the young planted cotton having from four to eight leaves. At Victoria, early in June, 1902, Mr. A. N. Caudell found, in examining 100 stubble plants growing in a planted field, that fully one-half of the squares upon these plants were then infested. The planted cotton was just beginning to form squares and was slightly injured at that time.

It appears, therefore, that stubble plants, where such exist, receive a large part of the first attack of the hibernated weevils, not because of any special attraction, but for the reason that they are present long before the planted cotton has come up. The occurrence of volunteer and stubble cotton in the fields in the early spring is of considerable importance in the boll-weevil problem. Throughout the coast regions, especially of southern Texas, stubble cotton is very common in the fields, and there is hardly a region of the South where volunteer cotton can not be found before the normal planting is up. (See Pl. VIII, *a*.)

It is by no means certain that all or even a large proportion of the hibernated weevils may be found upon the early plants, and this renders their use as traps entirely impracticable. A number of observations have shown that weevils frequently occur upon the planted cotton, even when numbers of vigorous stubble plants may be found within a comparatively short distance. In fact, at Victoria, Tex., in 1904, many weevils were found feeding upon the planted cotton for more than six weeks after the stubble plants were producing fruit.

DESTRUCTIVE POWER BY FEEDING.[1]

A glance at the figures in Table VIII is sufficient to show the great destructive power of the Mexican cotton-boll weevil. It may be seen that both in the field and in the laboratory the weevils of the first generation are more active in making punctures than are the hibernated weevils. These generations overlap too far to justify us in attributing this difference to the influence of a higher temperature alone, though this factor will account for a large part of it. A comparison of the figures for males alone with those for females alone or with those for males and females together shows that it is very conservative to state that males make less than half as many punctures as do females. By the habit of distributing their punctures among a greater number of squares the destructiveness of the females becomes at least five times as great as that of the males.

This great capacity for destruction has been one of the most evident points in the history of the spread of the weevil and has deeply impressed the entomologists who first studied the insect in Texas. In 1895 Mr. E. A. Schwarz, in writing of the work of the weevil at Beeville, said:

> Each individual specimen possesses an enormous destructive power and is able to destroy hundreds of squares, most of them by simply sticking its beak into them for feeding purposes.

ATTRACTIVENESS OF VARIOUS SUBSTANCES.

Experiments have proved that the report which has sometimes been circulated to the effect that cottonseed meal attracts the weevil is due to mistaking other insects for it. Many tests, both in the laboratory and in the field, have shown that sugar and molasses, either in solution or otherwise, have no attraction whatever for the weevil. Honey exerts a very weak attraction, but not enough to be of any practical use in control. In fact, it has not been found that any substance exerts a special attraction for the weevil. The experiments have dealt with many chemicals as well as plant decoctions.

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[1] Extracted from Bulletin 51, Bureau of Entomology, p. 61.

SENSE OF COLOR.

A series of interesting observations on the color sense of the boll weevil was made by Mr. C. R. Jones at Calvert and Victoria, Tex., and Alexandria, La., in 1907. Tubes of different colors were placed in a box, all with an equal amount of sunlight, and the weevils were given food. The observations were made at intervals during the day, and each time the weevils were all shaken back into the box. Table IX shows the total number of weevils found at each color for the series of observations and also the weighted average attractiveness. Fourteen shades were used, but these may be grouped under eight colors. The three most attractive shades were light-blue, dark-green, and light-pink. While it is rather difficult to explain the results, it nevertheless appears that there is some preference for certain colors on the part of the weevil.

TABLE IX.—*Relative attractiveness of colors to the boll weevil.*

Color.	Number of observations.	Number of weevils attracted.	Average attractiveness.
			Per cent.
Blue	64	461	7.2
Green	43	261	6.0
Yellow	32	123	3.8
Red	107	411	3.8
White	11	24	2.1
Purple	32	29	.8
Orange	10	5	.5
Black	21	6	.2

MOVEMENTS ON FOOD PLANT.

Various observations have been made to determine the amount of movement of weevils at night. In July, 1904, at a mean temperature of 76.3° F., Mr. A. C. Morgan found, in an aggregate of 134 weevil nights, that eight weevils had moved but 25 times. Each weevil had moved only once every six nights. On cloudy days weevils are much more sluggish than on sunny days. Relative humidity influences the activity, but no definite observations on this point have been made.

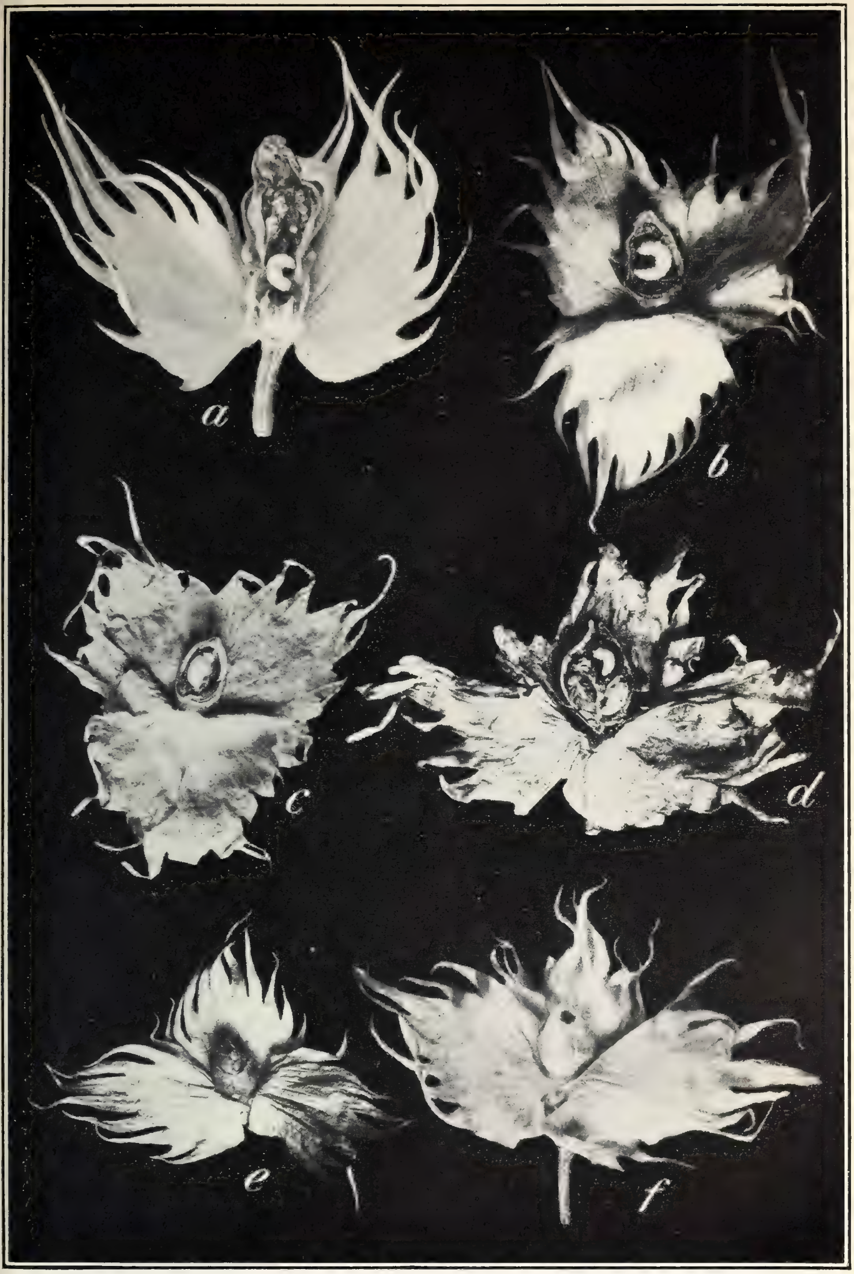
The effect of temperature on locomotive activity may well be illustrated by a series of laboratory experiments conducted by Dr. A. W. Morrill. A thermometer was passed through a cork and inclosed in a test tube, which in turn was placed within a hydrometer cylinder of sufficient depth to inclose it. Weevils were inclosed in the test tube with the thermometer, and the temperature of the cylinder was varied either by heating gently or by the use of ice water. Starting with the thermometer at 64° F., the 10 weevils inclosed were found to move slowly, half of them being quiët. As the temperature was gradually raised the activity of the weevils increased up to 105° F. When the temperature reached 95° F. or over the weevils were running up and down the tube. By filling the cylinder with cold water the temperature was lowered to 86° F., at which point the weevils began to cluster at the top on the cork and were crawling slowly. By the addition of ice in the cylinder the temperature was lowered to 59° F., at which point five weevils were struggling on the bottom of the test tube or clinging to one another, four were clustered on the stopper, while one was slowly crawling downward. At 50° F. six weevils at the bottom showed slight signs of life, and one was crawling slowly. At 45.5° F. slight signs of life were still shown, while at 40° F. occasional movements only were noted. When the temperature was raised weevils began crawling as 50° F. was passed, and at 64° all had left the bottom and were crawling upward. Some recovered more quickly than did others. The temperature was again lowered, this time by the use of salt with ice. All movement ceased at 37° F. The cooling, however, was continued to 33° F., after which it was slowly raised to 42° F., at which point movements began.

EFFECTS UPON SQUARES AND BOLLS OF FEEDING BY THE BOLL WEEVIL.

From numerous large, open feeding punctures a square becomes so severely injured that it flares very quickly, often within 24 hours. (See Pl. V, *c*.) Males usually make the largest punctures, which they always leave open while they remain for a day or more working upon the same square. It has been often found that squares thus injured by a male will flare before the weevil leaves it. The time of flaring depends upon the degree of injury and the size of the square. Thus small squares which receive only a single large feeding puncture in the evening are found widely flared in the morning. On the other hand, large squares which are within a few days of the time of their blooming may receive a number of punctures without showing any noticeable flaring. Frequently a square which has flared widely will be found later to have closed again and to have formed a distorted bloom, and occasionally such squares develop into normal bolls. (See Pl. V, *e*, *f*.) In squares of medium size a single feeding puncture does not usually destroy the square. The destruction of a square by feeding results either from drying or decay which follows the weevil injury.

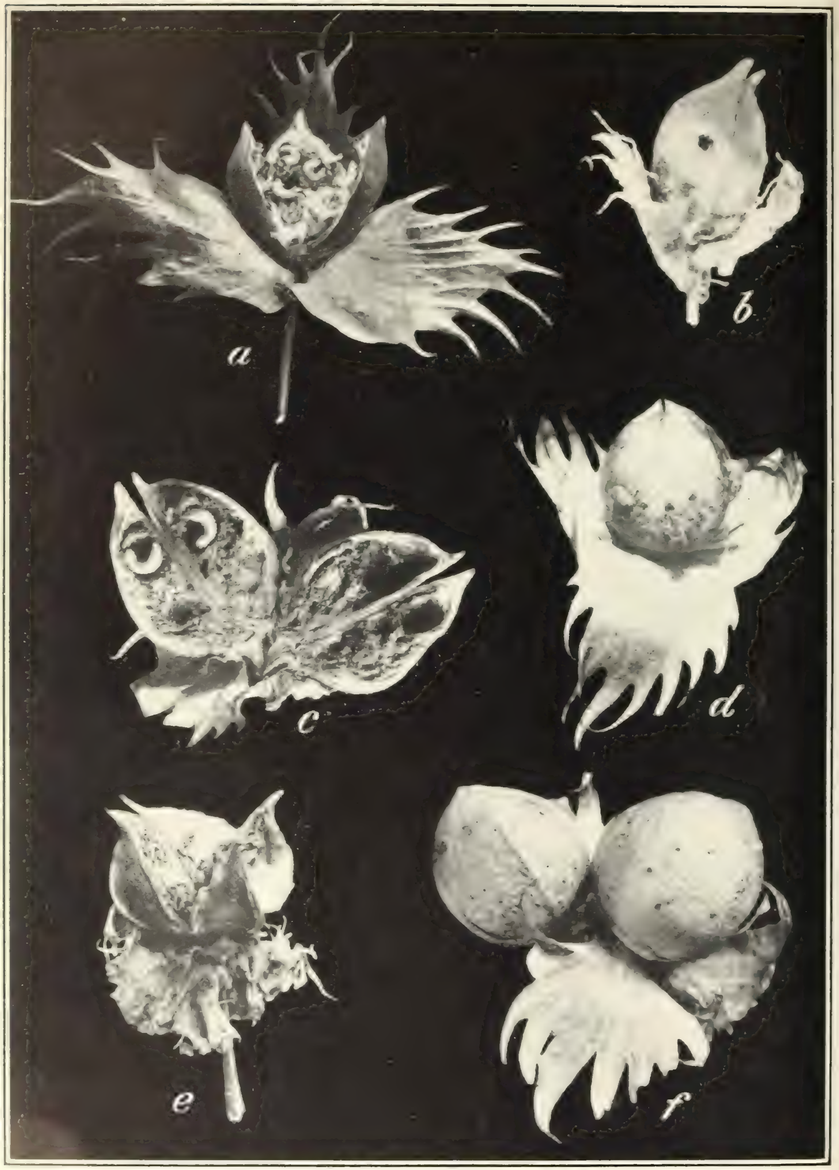
TABLE X.—*Destruction of squares by the feeding of the boll weevil.*

Period	Total number of squares punctured.	Number of squares with feeding punctures.	Total number of feeding punctures.	Average number of feeding punctures per square.	Average number of days before falling.
June-July	751	170	335	1.9	5.8
August-September	426	183	383	2.0	4.4
October-November	176	74	216	2.9	15.2
Total	1,353	427	934		
Weighted averages				2.0	7.0



INJURY BY BOLL WEEVIL TO SQUARES.

a, Bloom checked by attacks of larva; *b*, square opened, showing grown larva; *c*, square opened, showing pupa; *d*, dwarfed boll opened, showing one larva and two pupæ; *e*, weevil escaping from square; *f*, emergence hole of adult in square. (Original.)



INJURY BY BOLL WEEVIL TO BOLLS.

a, Three larvæ in boll; *b*, emergence hole in dry unopened boll; *c*, two larvæ in boll; *d*, weevils puncturing boll; *e*, opened boll, with two locks injured by weevil; *f*, large bolls severely punctured. (Original.)

Table X shows that the number of feeding punctures per square is determined by seasonal influences, as is also the average number of days before falling. A comparison of the average time from the date of the attack to the falling of the square shows that squares which are only fed on, fall, as a rule, somewhat more quickly than do squares which only contain larvæ and have never been fed upon. Flaring takes place more rapidly as the result of feeding injury by the adult than from oviposition and injury from the developing stage. While only one egg is generally laid in a square, it appears from Table X that two feeding punctures are usually made in a square.

Bolls are quite largely fed upon after infestation has reached its height. Small and tender bolls are often thoroughly riddled by the numerous punctures and fall within a short time. (See Pl. VII.) Larger bolls may receive many more punctures but do not fall. In bolls an abnormal woody growth sometimes takes the place of the punctured fiber, and a softening and decay of the seeds often accompanies this change. One or more locks may be destroyed, while the remainder of the boll develops in perfect condition.

SUSCEPTIBILITY OF VARIOUS COTTONS.[1]

During 1903 and 1904 experiments were conducted at Victoria, Tex., to ascertain the relative susceptibility of several varieties of American Upland, Sea Island, Egyptian, and Cuban cottons. The observations at the laboratory were made by carefully examining the plants, looking into each square, and removing every weevil and infested square found. If there were any distasteful or resistant cotton among these it would surely be found in this way, and if any variety were especially attractive to the weevils it would be equally apparent. Since infested squares were removed, the accident of association or proximity would not determine the location of the weevils found, but all might be considered as having come to the cotton with equal opportunities to make their choice of food, and accordingly their location has been considered as indicating such choice. The period of observation extended from June to November, except with the Cuban cotton, which was planted late and began to square during the latter part of August. For the purpose of this comparison both the several varieties and the various plats of the American cotton will be considered together, as no evidence of preference was found among them.

In making a comparison of the results three elements must be considered for each variety of cotton: First, the number of plants of each variety; second, the number of days during which each kind was under observation; third, the total number of weevils found on each class of cotton. The elements of numbers of plants and time under observation may be expressed by the product of those two factors forming a term which we may call "plant days." The total number of weevils found upon any class of cotton divided by the number of plant days will give the average number of weevils attracted by each plant for each day, and these numbers furnish a means of direct comparison and show at a glance the average relative attractiveness of each class of cotton. The results of this series of experiments are tabulated below:

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[1] The following discussion is extracted, but modified, from Bul. 51, Bureau of Entomology, pp. 61-64.

TABLE XI.—*Relative attractiveness of various cottons to the boll weevil.*

Class of cotton.	Number of plants.	Total.			Average.		Relative attractiveness.
		Plant days.	Weevils found.	Infested squares.	Weevils per plant per day.	Infested squares per weevil.	
1903.							
American	62	4,920	287	3,507	0.058+	12.2+	1.0
Cuban	5	120	11	136	.092−	12.4−	1.6+
Sea island	8	552	64	1,089	.116−	17.0+	2.0
Egyptian	8	808	207	2,013	.256+	9.7+	4.4+
Total of 3 non-American cottons	21	1,480	282	3,238	.191−	11.5−	3.3−
1904.							
American	60	3,780	346	....	.0914	....	1.0
Sea island	5	315	117	....	.371+	....	4.0
Egyptian	4	252	102	....	.405−	....	4.4+

An examination of Table XI shows that American Upland cotton is less subject to attack by the weevil than any of the others, and that Egyptian (*Mit Afifi*) is by far the most susceptible. The weevils gathered so thickly on the Egyptian cotton that the plants could not produce sufficient squares to keep ahead of the injury, and therefore the average number of squares for each weevil is only three-fourths as great with that variety as with the less-infested kinds, but the average injury to each square was greater than with any other. It is possible that the greater amount of nectar secreted by the Egyptian cotton plants is responsible for this increased attraction of the weevils.

The results are still further sustained by observations upon larger areas of American and Egyptian cotton under field conditions in three localities in Texas, no weevils being removed from either kind. At Victoria, Tex., on August 26, 1903, an examination showed that 96 per cent of Egyptian squares were infested, while an average of 13 fields of American showed 75.5 per cent. At Calvert, Tex., on September 4, Egyptian showed 100 per cent infested, while the American varieties growing alongside showed 91 per cent. Similar results were found at San Antonio. Though growing in close proximity, the Egyptian produced no staple whatever, while the American gave better than an average yield in spite of the depredations of the weevil.

At Victoria, in the experimental tract during 1904, three varieties of Egyptian cotton (Mit Afifi, Janovitch, and Ashmouni) were tested side by side with American varieties. The Egyptian varieties uniformly failed to make a pound of cotton, while the American varieties averaged 400 pounds per acre.

In accordance with these observations, it appears that in developing a variety of cotton which shall be less susceptible to weevil attack, by far the most promising field for work lies among the American varieties, and of these the very early maturing kinds are most promising.

The question of choice of different varieties for food was tested in the laboratory by Dr. A. W. Morrill, by placing squares of two kinds of cotton, American and Egyptian, in alternate rows in a rearing cage so lettered and numbered that each square could be exactly located. Weevils were then placed so that they could take their choice of these squares, and observations from 8 a. m. to 6 p. m. were made upon the location and activity of the weevils. Though this experiment was repeated four times no positive evidence was obtained to show that weevils had any choice as to which kind of squares they fed upon. Table XII presents a summary of these results.

TABLE XII.—*Rearing-cage observations upon boll weevil choice of American and Egyptian squares.*

Experiment.	Period of observation.	Number of observations.	Weevils used.	American squares.				Egyptian squares.			
				Total number.	Attacked.	Feeding punctures.	Egg punctures.	Total number.	Attacked.	Feeding punctures.	Egg punctures.
1	12 m. to 8 a. m.	8	10	16	12	15	5	16	5	12	3
2	11.45 a. m. to 9.45 a. m.	5	10	16	5	19	1	16	5	13	3
3	12 m. to 5 p. m. day after	5	10	16	7	25	2	16	9	27	2
4	11.45 a. m. to 9 a. m.	5	10	16	6	17	6	16	8	14	3
5	6 p. m. to 8 a. m.	1	18	4	2	7	0	4	2	10	0
	Total	24	58	68	32	83	14	68	29	76	11

In experiments 1 and 2 the American squares were attacked more extensively than were the Egyptian, while in experiments 3 and 5 greater injury was done to the Egyptian. In experiment 4 the smaller number of egg and feeding punctures made in the Egyptian squares is counterbalanced by the larger number of squares attacked. Although the totals from these five tests show slightly less injury to the Egyptian than to the American squares, it could hardly be expected that two arbitrarily chosen series, even if of the same variety, would show any closer agreement in the points of comparison made in this table than is therein shown by the American and Egyptian squares.

Field examinations made in Cuba and Mexico on the native varieties of cotton showed them to be as susceptible to serious weevil injury as are the cultivated cottons. In some localities in Central America the dwarf character of the cotton grown, the very open method of cultivation, and certain protective adaptations on the part of the plants result in the production of fair crops, though the varieties of cotton grown are by no means immune to weevil attack.

DURATION OF LIFE OF ADULT WEEVILS.

The subject of longevity is one which naturally divides itself into several headings. Many factors must be considered, among which are the nature of the food supply, seasonal conditions, the sex of the individual, and the time of entrance into and emergence from hibernation.

The maximum record of longevity of any boll weevil is that of a hibernated weevil at Tallulah, La. (1910), which was fed squares after emergence and lived a total of over 335 days. The maximum recorded period of hibernation without food is 240 days, and the maximum recorded length of life of hibernated weevils provided with food after emergence is 130 days for males at Dallas, Tex. (1907), and 118 days for females at Calvert, Tex. (1907). The maximum recorded length of life of hibernated weevils unfed after emergence is 90 days for males and 88 days for females, both records being made at Dallas in 1907.

A considerable number of records are available to illustrate the relative sustaining power of the various kinds of weevil food. (See Table XIII.) These records are especially valuable in making comparisons with the sustaining power of other plants suspected of being possible food plants. It will be noticed that the same food has varying sustaining power at different seasons.

TABLE XIII.

DURATION OF LIFE OF REARED BOLL WEEVILS WITHOUT NORMAL FOOD.

Season.	Sustenance provided.	Number of weevils.	Number of weevil days.	Average longevity.	Maximum longevity.
June-July	Hay	18	47.7	2.5	7
Do	Oats	15	44.9	2.9	7
Do	Corn	10	34	3.4	5
Total for reared weevils with grain.		43	126.6	2.9	7
July	Tie vine	5	15	3	3
May	Hibiscus leaf	2	6	3	3
July	Sunflower	5	16	3.2	4
May	Okra leaf	3	10	3.3	4
July	Pigweed	5	17	3.4	4
Do	Bloodweed	5	18	3.6	5
Do	Bermuda grass	5	19	3.8	5
Total for reared weevils on weed leaves.		30	101	3.3	5
June-July	Water	79	339.8	4.3	9
August-October	do	72	306.3	4.2	11
Total for reared weevils on water only.		151	646.5	4.28	11
June	Jap. Hibiscus buds	12	25	2.0	3
August	do	9	19	2.1	4
July	Callirrhoe buds	42	235	5.6	11
June	*Hibiscus africanus* buds	16	92	5.7	14
July	Hollyhock buds	3	18	6.0	+ 7
Do	*Hibiscus moscheutos* buds	6	36	6.0	8
June	Okra buds	10	78	7.8	10
September	*Hibiscus militaris* buds	42	305	7.2	10
September-November	do	18	486	27.0	[1]+43
Total for reared weevils on malvaceous buds.		158	1,294	8.1	43
September	Fresh sorghum cane	17	193	11.3	20
October-November—hibernation quarters offered.		26	626	24.0	45

DURATION OF LIFE (AFTER EMERGENCE) OF HIBERNATED WEEVILS WITHOUT NORMAL FOOD.

June-July	Excelsior	13	32.5	2.5	4
Do	Rice	14	45.2	3.2	4
Total for hibernated weevils without water.		27	77.7	2.8	4
March-May	Water	5,701	59,021.8	10.3	90

[1] This weevil then entered hibernation and remained therein 126 days.

On sweetened water 12 weevils lived an average of a little less than 6 days. Six weevils fed upon molasses alone lived an average of 11.5 days.

Without food or water 50 weevils, just developed but not fed, lived an average of 5 days; 15 which were 7 weeks old lived 6 days; and 18 which were one month old lived 7.5 days.

TABLE XIV.—*Duration of life of boll weevils with normal food.*

Season.	Sustenance provided.	Number of weevils.	Number of weevil days.	Average longevity.	Maximum longevity.
July–September	Bolls	37	684.5	18.5	+20
September–November	do	45	981.0	21.8	69
Total for weevils fed on bolls		82	1,665.5	20.3	69
February–July	Foliage	4,261	103,931.1	24.3	130
October–December	do	92	2,950.9	32.0	
Total for weevils fed on foliage		4,353	106,882.0	24.5	130
April–June	Squares	170	12,439.4	73.1	105
June–July	do	91	3,363.2	36.9	58
August–September	do	64	4,796.0	74.9	135
September–October	do	18	1,170.0	65.0	+76
October–December	do	10	359.0	35.9	
Total for weevils fed on squares		353	22,127.6	62.7	135

These records show the following longevity for weevils fed on different portions of the cotton plant: On bolls, 20.3 days; on foliage, 24.5 days; on squares, 62.7 days. The sustaining power of foliage is therefore about 20 per cent higher than that of bolls, and that of squares 150 per cent higher than that of foliage. This indicates that the squares are by far the most suitable form of food.

A number of observations were made on the relative longevity of weevils of different generations when fed upon cotton squares. Weevils of the first generation lived 57 days; of the third, 48.5 days, and of the fifth, 65 days.

Newly reared weevils evidently have not the vitality of weevils emerged from a long hibernation, for they can not live so long on water alone. The boll weevil can find nourishment in several species of malvaceous plants which will sustain life twice as long as water alone, and in certain conditions as long as cotton foliage. It is interesting to note that the sweetened water from sorghum cane had almost three times the sustaining power of pure water.

In connection with these studies figures were obtained upon the relative food value of the various foods to the two sexes. The data obtained may be tabulated as follows.

TABLE XV.—*Duration of life of boll weevils according to sex.*

Condition.	Season.	Food provided.	Males.			Females.		
			Number.	Weevil days.	Longevity.	Number.	Weevil days.	Longevity.
Hibernated	June	None	7	13.3	1.9	6	19.2	3.2
Reared	June-July	Hay	9	19.8	2.2	9	27.9	3.1
Do.	do	Oats	7	18.9	2.7	8	26.0	3.25
Do.	do	Corn	5	17.0	3.4	5	17.4	3.4
Hibernated	June	Rice	8	27.2	3.4	6	18.0	3.0
Reared	do	Water	4	14.8	3.7	8	30.8	3.85
Hibernated	March-June	do	2,638	27,052.5	10.2	1,980	19,895.5	10.0
Reared	July-September	Bolls	16	315.2	19.7	21	319.2	15.2
Hibernated	March-July	Foliage	1,672	42,185.7	24.6	1,337	34,752.1	25.9
Do.	do	Squares	90	7,207.0	80.0	68	4,752.0	69.8
Reared	July-October	do	57	3,198.0	56.1	44	2,432.0	55.2
Total			4,513	80,069.4	17.7	3,492	64,290.1	18.4

Table XV in some respects bears out other findings as to the superior hardihood of the female sex. It will be noticed that the female's superior vitality is shown in all the cases where the food supply is abnormal. Nevertheless, it is noticeable that in the case of weevils fed on squares and bolls the males had the greater longevity.

CANNIBALISM.[1]

It is hardly proper to speak of cannibalism as a food habit of the boll weevil, but the facts observed may well be recorded here. Under the impulse of extreme hunger weevils have several times showed a slight cannibalistic tendency.

Seven beetles were confined in a pill box without food. On the third day six only were alive. Of the seventh only the hardest chitinized parts (head, proboscis, pronotum, legs, and elytra) remained, the softer parts having been eaten by the survivors.

In another box containing 12 adults the leaf supplied for food was insufficient, and on the fourth day eight were dead, four were partly eaten, and others had lost one or more legs each.

In another case a few young adults and a number of squares containing pupæ were placed in a box together with a few fresh squares to serve as food for the adults. When the box was opened after a number of days one adult was found having its elytra eaten through and most of its abdomen devoured. In spite of this mutilation the victim was still alive and kicking slowly. The squares were still fresh and fit for food, so that this is really the clearest case of cannibalism observed.

Frequently more than one larva hatches in a square, and when this is the case a struggle between them is almost certain to take place before they become full grown. Many cases have been observed in which squares contained one living and one or more smaller dead larvæ, while in a few cases the actual death struggle was observed.

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[1] From Bulletin 51, Bureau of Entomology, p. 48.

SEASONAL PROPORTION OF SEXES.

The most careful records of the sexes have been made in connection with the hibernation period. The records are presented herewith in tabular form, grouping the specimens as hibernated weevils, reared weevils taken during the spring and summer, and autumn weevils which were about to hibernate:

TABLE XVI.—*Sex of hibernated boll weevils.*

Year.	Locality.	Male.		Female.	
		Number.	Per cent.	Number.	Per cent.
1902–03	Victoria, Tex	269	60.8	174	39.2
1903–04	Calvert, Tex	40	59.7	27	40.3
1903–04	Victoria, Tex	203	57.1	153	42.9
1905–06	Dallas, Tex	173	57.7	127	42.3
1905–06	Victoria, Tex	84	59.6	57	40.4
1906–07	Dallas, Tex	1,668	54.1	1,412	45.9
1906–07	Calvert, Tex	948	52.9	846	47.1
1906–07	Victoria, Tex	1,660	61.3	1,049	38.7
Total		5,045		3,845	
Weighted averages			56.8		43.2

TABLE XVII.—*Sex of spring and summer reared boll weevils.*

Year.	Locality.	Male.		Female.	
		Number.	Per cent.	Number.	Per cent.
1902	Victoria, Tex	240	48.0	260	52.0
1903	do	140	53.1	124	46.9
1906	Dallas, Tex	63	44.7	78	55.3
1907	Overton, Tex	9	47.4	10	52.6
1910	Tallulah, La	475	54.7	393	45.3
Total		927		865	
Weighted average			51.7		48.3

TABLE XVIII.—*Sex of autumn boll weevils ready to enter hibernation.*

Year.	Male.		Female.	
	Number.	Per cent.	Number.	Per cent.
1904	557	63.7	317	36.3
1904	31	62.0	19	38.0
1905	63	57.7	127	42.3
1906	173	68.9	78	31.1
1906	173	57.7	127	42.3
1906	19	57.6	14	42.4
1906	29	52.7	26	47.3
Total	1,045		708	
Weighted average		60.0		40.0
Total and weighted average for all seasons	7,017	57.2	5,418	42.8

From these determinations it appears that males are somewhat more numerous than females, the percentage based on our observations being 57.2 males to 42.8 females. It is noticeable also that the males are in preponderance throughout the year. Since the males are less active in their movements than are the females, the advantage of the existence of the majority of males becomes apparent. The larger number of males and the more active habits of the females serve to increase the chances for the meeting of the sexes.

It has been shown by rearing experiments conducted at low temperatures that the retardation of the development, such as is due to cold weather, favors the development of the males.

FERTILIZATION.

AGE AT BEGINNING OF COPULATION.

After the adult weevils have left the squares a certain period of feeding is necessary before they arrive at full sexual maturity. This period varies in length according to the temperature prevailing and appears to bear about the same ratio to the developmental period as does the pupal stage. With weevils fed upon leaves alone the period preceding copulation is about twice the normal length, in the cases observed, of those having squares to feed upon. Mr. Cushman, in observations at Tallulah, La., in 1910, found that the period from emergence of the female to copulation varied from two to seven days, with an average of 4.4 days. During hot weather it is probable that this period averages three or four days, but as the weather becomes colder it increases gradually until the weevils may become adult, feed for a time, and go into hibernation without having mated. It should not be understood, however, that weevils do not usually copulate before hibernation. Mr. C. E. Hood made numerous observations of the exercise of this function in the fall of 1909 at Mansura, La.

SEXUAL ATTRACTION AND DURATION OF COPULATION.

The distance through which the attraction of the female insect will influence the male varies extremely. In observations made by Dr. Hinds at Victoria, Tex., it was found that the male was unable to recognize the female at a much greater distance than an inch. Observations carried on in the field, as well as in the laboratory, tend to show that the sexes are attracted only when they meet, as they are likely to do either on the stems or upon the squares of the plant.

In a considerable number of cases that were timed the average duration of the sexual act was very nearly 30 minutes. The earliest spring records of copulation available are for April 15.

DURATION OF FERTILITY.

A number of females which were known to have mated were isolated to determine the duration of fertility. Although the limit was not determined exactly, the results proved very striking. Several of the females laid over 225 eggs each, and nearly all of them proved fertile. Selecting three cases in which the facts are positively known, it appears that fertility lasted for an average of something over 66 days and that during this period these females deposited an average of nearly 200 eggs. The maximum limits may possibly be considerably higher. In fact, a single union seems to insure the fertility of as many eggs as the average female will lay, and its potency certainly lasts for a period fully equal to the average duration of life. It is probable, however, that there are many cases of repeated fertilization of females.

PARTHENOGENESIS.

Several series of experiments were conducted at Dallas, Tex., in August, 1906, to determine whether the boll weevil can reproduce parthenogenetically. Mr. R. A. Cushman kept 24 unfertilized females in confinement for 259 weevil days, and found that they deposited only 43 eggs, all being placed outside of the squares. No fertile eggs were laid. The rate of oviposition was one egg per female every six days. With a similar purpose Dr. Hinds isolated 40 individuals as soon as they matured.[1] Each beetle was supplied daily with fresh, clean squares and careful watch was kept for eggs. The first point noticed was that no eggs were found till the weevils were about twice as old as females usually are when they deposit their first eggs. After they began to oviposit it was found that a very small proportion of the eggs were deposited in the usual manner within sealed cavities in the squares, but nearly all of them had been left on the surface, usually near the opening of an empty egg puncture. This same habit was shown by a number of females, and so can not be ascribed to the possible physical weakness of the individuals tested. The number of eggs deposited was unusually small, and the few placed in sealed cavities failed to hatch. After somewhat more than a month had been passed in isolation a few pairs were mated to see if any change in the manner of oviposition would result. The very next eggs deposited by these fertilized females were placed in the squares and the cavities sealed up in the usual manner, showing that the infertile condition had been the cause of the abnormal manner of oviposition.

OVIPOSITION.

AGE AT BEGINNING OF OVIPOSITION.

As has been shown, normal oviposition never takes place until after fertilization has been accomplished, but it usually begins soon afterwards. Observations upon the age at which the first eggs are deposited can be made more easily and more positively than those upon the age at which fertilization takes place. In a general way, therefore, the observations here given may be cited as also throwing light upon the time of beginning copulation. Table XIX is introduced to summarize the various observations which have been made upon the period preceding oviposition. It will be noticed that the range is from 4 to 14 days during the breeding season. Of course, the weevils which hibernate before ovipositing are not to be considered as of this category.

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[1] Bulletin 51, Bureau of Entomology, pp. 91, 92.

TABLE XIX.—*Age of the boll weevil at beginning of oviposition.*

Date adult.	Place.	Date first egg.	Number of females.	Number weevil days.	Average age.
June 8-14, 1903	Victoria, Tex	June 16-19	27	150.0	5.55
July 8-11, 1910	Tallulah, La	July 14-19	11	66.0	6.00
July 29-31, 1910	do	Aug. 5-7	7	44.0	6.29
Aug. 14-22, 1910	do	Aug. 21-28	16	106.0	6.66
Sept. 4-9, 1902	Victoria, Tex	Sept. 16-17	8	72.5	9.06
Sept. 10-20, 1910	Tallulah, La	Sept. 18-Oct. 8	9	116.0	12.89
Oct. 2, 1902	Victoria, Tex	Oct. 16	4	56.0	14.00
Nov. 9-11, 1902	do	Nov. 16-19	10	73.0	7.30
June 8-Nov. 11		June 16-Nov. 19	92	683.5	7.40

EXAMINATION OF SQUARES BEFORE OVIPOSITION.

In the course of a great many observatious upon oviposition it was found that females almost invariably examine a square carefully before they begin a puncture for egg deposition. This examination is conducted entirely by means of senses located in the antennæ and not at all by sight. In fact, the sense of sight appears to be of comparatively small use to this weevil. In regard to the actual time spent in the work of examination before beginning a puncture, over sixty observations are recorded. These show that the average time is over two minutes. This examination of squares is made by females only when they intend to oviposit. Males have never been observed acting in this way, nor do females generally do so when their only object is to feed.

SELECTION OF UNINFESTED SQUARES FOR OVIPOSITION.

The sense by which the weevil examines the squares frequently enables it to detect an infested condition when no external sign is visible. Females sometimes refrain from placing eggs in squares, even when they are apparently searching for a place to oviposit and anxious to do so. The acuteness and accuracy of the preliminary examination is well shown by the fact that when provided with more squares than they have eggs to deposit they do not often place more than one egg in a square. Where a totally infested condition is reached, as is frequently the case in the field, no choice between infested and uninfested squares could be exercised, and then, unless the female happens to be in a condition to refrain from oviposition, she is forced to deposit more than one egg in a square. Table XX illustrates the distribution of egg and feeding puncture as collated from many records.

TABLE XX.—*Selection of squares and relation of feeding to oviposition of the boll weevil.*

Place and time of observation.	Total squares attacked.	Squares with 1 egg each.		Squares with more than 1 egg each.		Squares with both egg and feeding punctures.		Squares fed on only.	
		Number.	Per cent of total squares.	Number.	Per cent of total squares.	Number.	Per cent of total squares.	Number.	Per cent of total squares.
In laboratory, 1902	630	477	75.7	19	3.0	24	3.8	110	17.4
In field, 1902	151	56	37.0	33	21.8	46	30.4	16	10.5
In field, 1903	560	317	55.9	83	14.8	50	8.9	110	19.6
In field, 1905	1,036	531	51.2	415	40.0	90	8.6	0	0.0
In field, 1907	2,679	413	15.4	0	0.0	1,832	68.4	434	16.2
Total	5,056	1,794		550		2,042		670	
Average percentage			35.4		10.8		40.3		13.2

The observations show that 86.7 per cent of all squares attacked received eggs. It may also be seen that 40.9 per cent of all squares oviposited in received only one egg each. The squares which were only fed upon formed but 13.2 per cent of the total number attacked, and, as has been shown above, those receiving both egg and feeding punctures constituted 40.3 per cent. As the weevil injury overtakes the production of squares the proportion of squares containing both egg and feeding punctures increases rapidly. Where several eggs are placed in a square it is rarely the case that more than one larva develops.[1] If two or more hatch in a square one is likely to destroy the others when their feeding brings them together. Should eggs be placed in squares which already contain a partly grown larva, those hatching would probably find the quality of the food so poor that they would soon die without having made much growth. Since one egg will insure the destruction of the square and a number of eggs would do no more, it is plain that the possible number of offspring of a single female is increased directly in proportion to the number of her eggs that she places one in a square. Favorable food conditions for the larva are likewise best maintained by the avoidance of feeding upon squares in which eggs have been deposited and also by refraining from ovipositing in squares which have been much fed upon. Selection of uninfested squares is, therefore, of the greatest importance in the reproduction of the weevil, since this insures the most favorable conditions for the maturity of the largest possible number of offspring.

Feeding and oviposition are common in the same boll, but unless the infestation is very heavy it appears that only rarely is more than one egg placed in one lock, though several are often deposited in the same boll. The number deposited depends considerably upon the size of the boll. The smallest, which have just set, receive but one, as do the squares, and these fall and produce the adult weevil at about the same period as in the case of squares. Bolls which are larger when they become infested have often been found to be thickly punctured and to contain 6 or 8, and in one case 15, larvæ. (See Pl. VI, *d;* Pl. VII, *c*.)

DEPENDENCE OF REPRODUCTION UPON FOOD OBTAINED FROM SQUARES.[2]

During the fall of 1902 a series of experiments, lasting for 12 weeks, was made to determine the length of life of weevils fed solely upon leaves. In one lot, consisting of nine males and eight females, the average length of life of the females was 25 days, while that of the males was 36 days. Though this period far exceeded the normal time usually passed between the emergence of adults and the beginning of egg deposition, no eggs were found. Dissection of the females which lived longest showed that their ovaries were still in latent condition, though the weevils were then 81 days old. Few instances of copulation were observed among weevils fed upon leaves alone, and among nearly 70 weevils which were thus tested no eggs were ever deposited. After a period of three weeks upon leaves, 11 weevils were transferred to squares. Females in this lot began to lay in four days, and four of them deposited 323 eggs in an average time of 20 days. The conclusion seems plain that so long as leaves alone are fed upon, eggs do not develop, while a diet of squares leads to the development of eggs in about four days. It is worthy of note that the interval between the first feeding upon squares and the deposition of the first eggs is almost the same with these weevils taken in middle life as with weevils which have just emerged.

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[1] In one case four normal pupæ were found in a single square. This observation was made at Shreveport, La., by Mr. H. Pinkus.

[2] From Bull. 51, Bureau of Entomology, pp. 112, 113.

An examination of hibernated females taken in the spring of 1903, which had fed for six weeks upon cotton leaves, showed that their ovaries were still latent. Copulation was rarely observed among hibernated weevils until after squares had been given them. In a few days after feeding upon squares, mating and oviposition began. The average period was from three to five days, and, having once begun, oviposition continued regularly.

It has been found that food passes the alimentary canal in less than 24 hours. Assimilation therefore must be very rapid. It is evident that while leaves will sustain life certain nutritive elements found only in squares are essential in the production of eggs.

These experiments were repeated in 1904 with similar results.

Upon dissecting weevils just taken from hibernation, it was found that females contained no developed eggs, but that their ovaries were in an inactive condition, similar to those of females which had fed for months entirely upon leaves during the previous fall. Upon examining females taken from stubble cotton later in the spring, but before squares had appeared, it was found that they also were in similar condition. This was also true of females kept in the laboratory from the time of emergence from hibernation until squares became abundant, with only leaves for food. It seems peculiar that upon a purely leaf diet eggs are not developed, but all observations made indicate that this is the case. It can not be said definitely whether the females examined had been fertilized, but it is certain that they were not ready to deposit eggs.

PLACE OF EGG DEPOSITION.

The location of egg punctures, while variable, still shows some selection on the part of the weevil. This may be due partly to the form of the squares and partly also to the size of the weevil, but whatever the explanation, the fact remains that in a majority of cases the egg puncture is made on a line about halfway between the base and the tip of the square. When so placed the egg rests either just inside the base of a petal or among the lowest anthers in the square, according to the varying thickness of the floral coverings at that point. Punctures are very rarely made below this line, though they are sometimes made nearer the tip. Almost invariably the egg puncture is started through the calyx in preference to the more tender portion of the square, where the corolla only would need to be punctured. With bolls no selection of any particular location has been found, but eggs seem to be placed in almost any portion.

THE ACT OF OVIPOSITION.

While engaged in making egg punctures, the favorite position of the weevil is with its body parallel to the long axis of the square and its head toward the base. The tip of the weevil's body is thus brought near the apex of a medium-sized square. It may be that the position described is especially favorable for obtaining a firm and even hold and this may have something to do with the regularity with which it is assumed. Having selected her location, the female takes a firm hold upon the sides of the square and completes her puncture while in this position.

The female begins drilling a hole by removing with the mandibles a little flake of the outer epidermis. Then, with her feet strongly braced by gnawing and pushing with an auger-like motion, she thrusts her beak into the tender portion of the square. At the bottom of the puncture she makes a small cavity by gnawing, at the same time moving about the hole with the beak as a pivot. Withdrawing her beak, she turns about with the center of her body as a pivot. This places the tip of her abdomen directly over the puncture, into which she thrusts her ovipositor. The ovipositor is protruded to the bottom of the cavity in which it appears to be firmly held in position by the two terminal papillæ and the enlarged terminal portion. Slight contractions of the abdomen occur while this insertion is being made. In a few moments much stronger contractions may be seen, and often a firmer hold is taken with the hind legs as the egg is passed from the body, and its movement may be seen as it is forced along within the ovipositor and down into the puncture. Only a few seconds are required to complete the deposition after the egg enters the opening to the cavity. Having placed the egg, the ovipositor is withdrawn, and just as the tip of it leaves the cavity a quantity of mucilaginous material, usually mixed with some solid excrement, is forced into the opening and smeared around by means of the tip of the abdomen. This seals the egg puncture, and the act of oviposition becomes complete. Sometimes the weevil fails to locate the puncture immediately with her ovipositor. In this event she searches excitedly, moving the tip of the abdomen about feeling carefully over the surface of the square. In this search, however, she never moves her front feet, apparently using the position of these as a guide to the distance through which she should search. Failing to locate the puncture in this way she again turns around and searches for it with her beak and antennæ. When the cavity has been found again the female invariably enlarges it before turning again to insert the ovipositor. If the search with the antennæ does not prove successful, the female generally makes another puncture in the same manner as at first.

The usual habit of the female in puncturing through the calyx enables it to seal the wound more thoroughly because of the healing power possessed by the calyx tissue. Punctures made in the corolla must remain open or are closed only by the slight filling of mucilaginous excrement by the weevil. Punctures through the calyx will, in most cases, be healed by the natural outgrowth of the tissue so as completely to fill the wounds in a manner analogous to the healing of wounds in the bark of a tree. The custom of the weevil in sealing up its egg punctures with a mixture of mucous substance and excrement is of great advantage and assistance to the plant in the healing process. While undoubtedly applied primarily as a protection to the egg, it serves to keep the punctured tissues from drying and decay, and thus promotes the process of repair. As a result of the growth thus stimulated in the calyx, the wound is healed perfectly in a short time, and a corky outgrowth appears above the general surface plane. This prominence has been termed a "wart." The healing is completed even before the hatching of the egg takes place, and thus both egg and larva partake of the benefit of its production. Occasionally warts develop from feeding punctures which were small, but the exact conditions under which this takes place have not been determined. Nevertheless, the presence of warts is the most certain external indication of oviposition in squares. In a series of observations they were found to follow oviposition in 84 per cent of the cases.

TIME REQUIRED TO DEPOSIT AN EGG.

Careful observations have been made upon the time of egg deposition. As in all other processes of the life history of this insect, the period of egg deposition is influenced by climatic conditions. It was found at Tallulah, La., in the early part of the summer of 1910, that the time required for making the puncture varied from 1 minute and 20 seconds to 8 minutes and 27 seconds, with an average of 3 minutes and 36 seconds. On the other hand, at Victoria, Tex., in October, the average time was 5¼ minutes, and the range from 1 to 13 minutes. At Tallulah the period for the deposition of the egg and the sealing of the puncture varied from 2 minutes and 45 seconds to 9 minutes and 30 seconds, with an average of 4 minutes and 41 seconds. At Victoria the period ranged from 3 to 16 minutes and averaged 7½ minutes.

STIMULATING EFFECT OF ABUNDANCE OF SQUARES UPON EGG DEPOSITION.[1]

Four actively laying females were confined together upon a few squares from September 22 to October 14, 1902. During this period they laid a total of 227 eggs, or an average of 2.37 eggs per weevil per day. For the next 13 days these same weevils were isolated and supplied with an abundance of squares. During this shorter period they laid 236 eggs, or 4.54 eggs per female daily.

These figures are the more striking, because the stimulation was plainly shown in spite of the general tendency to lay fewer eggs as the weevils grow older and as the average temperature becomes lower.

ACTIVITY OF WEEVILS IN DIFFERENT PARTS OF THE DAY.

Two series of observations have been carried on to determine the hourly activity of the weevils. The experiments at Victoria were conducted in the early part of September, when the temperature was ranging from a little under 70° F. to 95° F. during the day. It was found that there was almost a perfect coincidence between the temperature curve and the curve of the average activity of the females in ovipositing. This is shown in the accompanying diagram (fig. 5).

It also appeared that the activity of the weevils began and ceased at about 75° F. Perhaps this indicates that the act of oviposition requires a zero of effective temperature different from that of development. This would be entirely analogous to conditions in flowers, where it is found that the various functions of the plant are governed by independent laws of effective temperature. It appears also that the activity is much less on cloudy days than on clear days. At Tallulah, La., in 1910, observations were made on the periodic division of daily oviposition. The results are shown in Table XXI.

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[1] Modified from Bulletin 51, Bureau of Entomology, pp. 87, 88.

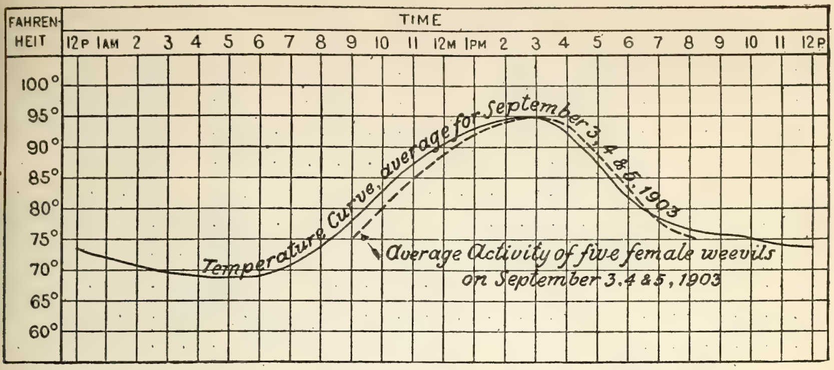

FIG. 5.—Diagram showing average activity of five female boll weevils. (After Hunter and Hinds.)

TABLE XXI.—*Summary of periodic division of oviposition, based upon nine boll weevils, Tallulah, La., July, 1910.*[1]

Period.	Total eggs laid.	Average number of eggs per hour.	Per cent of total oviposition in each period.	Average eggs per weevil per hour.
5 p. m.–7.30 p. m	25	5.00	23.15	0.63
7.30 p. m.–4 a. m	10	.59	9.26	.07
4 a. m.–9 a. m	21	2.10	19.44	.26
9 a. m.–1 p. m	17	2.13	15.74	.27
1 p. m.–5 p. m	35	4.38	32.41	.55

From these records it may be seen that the warmest part of the day is the most active period for the weevils.

SEASONAL RATE OF OVIPOSITION.

Since the period of reproductive activity of the boll weevil is so long, the rate at which eggs are deposited is a question requiring much time for its determination. The rate of oviposition is at least as strongly influenced by variations in temperature as is the rate of development, and it is very probable that some of the previously unaccountable and abrupt variations in the rate upon succeeding days may be explained by the relative humidity or by the amount of sunshine. The rate is influenced also by the abundance of clean squares which the weevil can find, so that it is greater in the early part of the season as the degree of infestation is approaching its limit than after infestation has reached its maximum. Several series of observations have been made upon the rate of egg deposition. These have been tabulated below in Table XXII.

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[1] From Cushman, Journ. Econ. Ent., vol. 4, p. 436.

TABLE XXII.—*Seasonal rate of oviposition of the boll weevil.*

Place.	Time.	Number of females.	Number of weevil days.	Average period of oviposition.	Total number of eggs.	Average number of eggs daily.	Average total number per female.	Maximum number in one day.
Victoria, Tex.	Aug.-Dec., 1902	[3] 1	135	135	255	1.88	255.0	....
Do.	Sept.-Oct., 1902	40	247	6	1,248	5.05	31.2	....
Do.	do.	4	23 13	9	227 236	2.37 4.54	116.0	....
Do.	Oct.-Dec., 1902	9	352	39	990	2.81	110.0	....
Do.[1]	May-July, 1903	[3] 51	2,018	39	5,254	2.60	103.0	18
Do.[2]	June-Sept., 1903	[3] 24	1,395	58	3,541	2.53	147.5	....
Do.	Aug., 1904	3	21	7	112	5.32	37.3	....
Terrell, Tex.	Sept., 1904	4	12	3	55	4.56	13.7	....
Dallas, Tex.	July-Aug., 1905	2	23	11	81	3.68	40.5	8
Do.	Aug.-Sept., 1905	3	108	36	233	2.15	77.6	20
Tallulah, La.[1]	June-Aug., 1910	[3] 9	310	34	1,830	5.90	203.3	20
Do.[2]	Aug.-Oct., 1910	[3] 4	183	45	887	4.85	221.7	12
Total		154	4,840	....	14,949	....	....	20
Average		....	....	31	....	3.13	97.07	....

[1] Hibernated weevils.
[2] First generation weevils.
[3] Observed for entire oviposition period and used in discussion of fecundity.

The influence of temperature upon the rate of oviposition may be shown by the following diagram (fig. 6), which expresses in a single line the mean number of eggs laid daily at a given temperature. There is, of course, more or less fluctuation from the mean, and it is due mostly to differences in humidity.

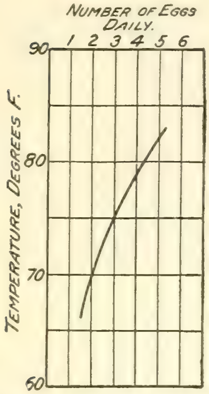

FIG. 6.—Diagram to illustrate influence of temperature on average rate of oviposition of boll weevil. (Original.)

The maximum number of eggs deposited by any weevil in one day has been recorded by Mr. Cushman as 20 at Tallulah, La. At Victoria, Tex., Dr. Morrill recorded two weevils to have laid 108 eggs in three days, or at the rate of 18 eggs per day. Dr. Morrill found that the size of weevils did not affect the rate per day, as four very small females laid 761 eggs at the rate of 3.3 eggs per day. It will be noticed that this rate is higher than the average of all the records in Table XXII. The number of eggs produced on the first day of oviposition varies from one to seven. About 67 per cent of the weevils at Victoria were found to oviposit fewer than three eggs on the first day.

IS THE FECUNDITY OF THE WEEVIL DECREASING?

In view of the fact that recent observations have shown a decrease in the fecundity of the gipsy moth in Massachusetts,[1] we have selected from the foregoing table (Table XXII) on the seasonal rate of oviposition the rather meager data bearing on the question of whether the fecundity of the boll weevil is decreasing. We find 76 weevils at Victoria, Tex., in 1902 and 1903, laying an average of 119 eggs in an average period of 46 days, and at the rate of 2.6 eggs per day, with a maximum of 18 eggs in one day; while at Tallulah, La., in 1910, 13 weevils laid an average of 209 eggs in an average period of 37 days and at the rate of 5.7 eggs per day, with a maximum of 20 eggs in one day. While these facts appear to indicate that the fecundity of the weevil is not decreasing, they do not, on the other hand, because of the great difference in the places of observations, prove an increase. More detailed data will be obtained on this point in the future.

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[1] Howard and Fiske, Bull. 91, Bur. Ent., U. S. Dept. Agr., pp. 109, 110, 1911.

PERIOD OF OVIPOSITION.

With the exception of hibernated weevils it appears that oviposition begins with the majority of females in about seven days after they emerge as adults to feed and continues uninterruptedly until shortly before death. In the case of 43 weevils observed at Tallulah, La., in 1910, the average preoviposition period was 7.72 days, the minimum 5, and the maximum 23 days. While females frequently deposit their last eggs during the last day of their life, a period of a few days usually intervenes between the cessation of oviposition and death.

The known maximum number of eggs laid by a single individual is 304. This was in the case of a weevil which lived for 275 days and deposited eggs at the rate of 7.6 eggs per day for 41 days. The maximum period of oviposition recorded is 135 days. In the case of 52 hibernated weevils at Victoria the period of oviposition averaged about 48 days, the maximum being fully 92 days. In an average rate with 21 females in the first generation the actual period was almost 75 days, the maximum being 113 days. The average period for the females of the first two generations appears to be longer than that for any other. In the third generation the average period for 11 females was 58 days, the maximum being 99 days, and in the fifth generation for 5 females the period averaged 48 days, with the maximum only 62 days. At Tallulah, La., in 1910, the average oviposition period was found to be 34.44 days. The average period for all of the records available is but 31 days.

The approach of cold weather cuts short the activity of the weevils which become adult after the middle of August, thereby decreasing the length of their oviposition period. Weevils which pass through the winter usually live longest, but as it requires more or less vitality to pass through the long hibernation period, their activity in the spring is thereby lessened.

EFFECTS OF OVIPOSITION UPON SQUARES.

As has been explained elsewhere, the attack of the weevil on the square causes it to form an absciss layer, which ultimately causes it to separate entirely from the plant. One of the immediate effects of attack is the flaring of the square, that is, the spreading of the bracts and their subsequent yellowing and drying. (See Pl. I.) Flaring may result from many other causes besides boll-weevil injury. When resulting from weevil injury it does not begin, as a rule, immediately after the injury, but only within from one to three days of the time when the square will be ready to fall. In especially severe cases of feeding injury flaring often results in less than 24 hours. Occasionally the growth of the square overcomes the injury from feeding, and the bracts, after having flared, again close up and the square continues its normal development and forms a perfect boll. When injured by the feeding of a young larva as the direct result of successful oviposition, flaring was found in 193 cases to take place in an average of 7 days from the deposition of the egg. (See Pls. V, VI.)

After an average period of 2.5 days subsequent to flaring the square was found to fall to the ground, although it may sometimes hang by a thread of the bark. The average time from egg deposition to the falling of the square in 539 cases from June to September was found to be about 9.6 days, which is about the middle point of the weevil development. It has been shown in another place (Table XXVII) that the period before the falling of the square has a direct bearing upon the period of the development of the weevil.

PROBABLE ORIGINAL BREEDING HABIT.

There is nothing to indicate that the boll weevil has changed its food plant, although it may have done so. It is now confined, as far as we know, to the various species and varieties of the genus Gossypium. The boll weevil belongs to a genus of weevils every species of which is confined in its food habits to a single species or genus of food plants. The majority of the species of Anthonomus and perhaps all that belong to the true genus normally breed in buds. It is therefore reasonable to assume that the normal habit of the boll weevil is to breed in the cotton buds or "squares," and that its habit of breeding in the bolls is an adaptation due to the necessity of providing for the great number of weevils which develop in the later part of the season. A study of the length of the development of many species of Anthonomus leads the authors to believe that the short developmental period in squares is perfectly normal and that the longer period in bolls is due merely to environmental conditions, as is explained under the subject of development.

THE EGG.

DURATION OF EGG STAGE.

Concealed as the eggs are beneath several layers of vegetable tissue, it is impossible to examine them to ascertain the exact length of the egg stage without in some degree interfering with the naturalness of their surroundings. The beginning of the stage is easily obtained by confining female weevils with uninfested squares. By making a large series of observations about the time that the larvæ should hatch it is possible to obtain the average length of the egg stage. The extreme range which has been observed in the duration of this stage is from 1 to 17 days, while the average period for the whole number of observations is but 3.7 days. It is possible that the embryo can undergo an even greater retardation without losing its vitality. The period of embryonic development is lengthened by decreases in the temperature and also by lowered atmospheric humidity. Thus it was found that between 79° F. and 81° F. the egg stage averaged 1.9 days at Alexandria, La., 2.61 days at Tallulah, La., 3.73 days at Victoria, Tex., and 4.1 days at Dallas, these differences corresponding quite regularly to the differences in the humidity of the various places. Table XXIII is presented to show the data which have been obtained on this stage, and is accompanied by two diagrams (figs. 7 and 8) to illustrate the relationship between mean temperature and the length of the egg period.

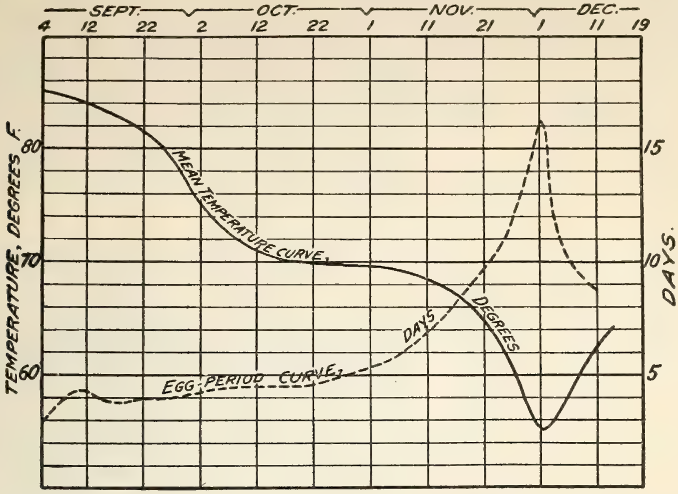

FIG. 7.—Diagram illustrating relationship of temperature to the egg period of the boll weevil at Victoria, Tex., in 1902. (Original.)

TABLE XXIII.—*Duration of the egg stage of the boll weevil.*

Place.	Year.	Eggs laid.	Eggs hatched.	Number of eggs laid.	Total number of egg days.	Average period.	Mean temperature.
						Days.	° *F.*
Victoria, Tex	1902	Sept. 4–29	Sept. 7–Oct. 3	384	1,434	3.73	81.0
Do	1902	Oct. 7–20	Oct. 11–24	95	430	4.52	73.0
Do	1902	Nov. 7	Nov. 13	12	72	6.0	
Do	1902	Nov. 24–28	Dec. 5–15	17	214	12.59	62.0
Do	1902	Dec. 2–9	Dec. 15–18	19	264	13.9	
Do	1903	May 27–June 5	May 30–June 9	25	93	3.75	72.5
Alexandria, La	1907	Aug. 31–Sept. 5	Sept. 2–7	229	436	1.9	79.2
Dallas, Tex	1908	July 17–20	July 20–23	35	145	4.1	81.6
Do	1908	Aug. 14	Aug. 17	11	33	3.0	88.0
Tallulah, La	1910	June 27–July 10	July 1–12	44	115	2.61	78.9
Total				871	3,236		
Average						3.7	74.6

HATCHING.

While still within the egg the larva can be seen to work its mandibles vigorously, and although a larva has never been seen in the act of making the rupture which allows it to escape from the egg, it is believed that the rupture is first started by the mandibles. The larvæ do not seem to eat the membranes from which they have escaped, but owing to the extreme delicacy of the skin it is almost impossible to find any trace of it after the larva has left it and begun feeding on the square, the membranes having been found in only a few cases.

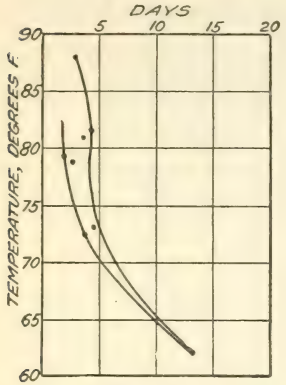

FIG. 8.—Diagram illustrating relationship of temperature to the egg period of the boll weevil and showing variations due to humidity. (Original.)

HATCHING OF EGGS LAID OUTSIDE OF COTTON FRUIT.

It occasionally happens that a female is unable to force an egg into the puncture prepared to receive it, and the egg is laid on the outside of the square or boll. Eggs so placed usually shrivel and dry up within a short time. To test the possibility of a larva making its way into the square from the outside a number were protected from drying. Of the 19 eggs tested, 6 hatched in from two to three days. In no case, however, was the young larva able to make its way into the square, and it soon perished. The hatching of eggs laid outside, therefore, appears to be of no importance, since the larvæ must perish without doing any damage.

On August 23, 1906, Mr. R. A. Cushman observed the hatching of two larvæ under water from eggs which had been submerged over 24 hours.

EATING OF EGGS DEPOSITED OUTSIDE.

The number of eggs left outside increases as the female becomes weakened and is especially noticeable shortly before her death. Repeated observations have shown that unfertilized females generally deposit their eggs on the outside, and only occasionally is an infertile egg deposited normally, though the attempt is regularly made to do so. The number of such eggs which may be found is greatly decreased by a peculiar habit observed many times, which will be described. Occasionally it appeared that the puncture which the female had made for the reception of an egg was too narrow to receive it, and after a prolonged attempt to force it down the female would withdraw her ovipositor, leaving the egg at the surface. She would then turn immediately and devour the egg. In some cases more than one has been devoured after repeated failures to place them properly in the squares.

PERCENTAGE OF EGGS THAT HATCH.

Definite records have not been kept regarding the percentage of eggs that hatch, but in the many hundreds of eggs followed during these observations very few have failed to hatch. Though some are much slower in embryonic development than are others laid at the same time and by the same female, it is probable that less than 1 per cent of the eggs are infertile or fail to hatch. It must be considered, however, that proliferation crushes many eggs. This proliferation is most aggressive against the eggs in the bolls in the late fall.

THE LARVA.

FOOD HABITS.[1]

It is plainly the instinct of the mother weevil to deposit her egg so that the larva upon hatching will find itself surrounded by an abundance of favorable food. In the great majority of cases this food consists principally of immature pollen. This is the first food of the larva which develops in a square, and it must be both soft and nutritious. Often a larva will eat its way entirely around the inside of a square in its pursuit of this food. In most cases the larva is about half grown before it feeds to any extent upon the other portions of the square. It may then take the pistil and the central portion of the ovary, scooping out a smoothly rounded cavity for the accommodation of its rapidly increasing bulk. So rapidly does the larva feed and grow that in rather less than a week it has devoured two or three times the bulk of its own body when fully grown. It sometimes happens that the square is large when the egg is deposited therein, and the bloom begins to open before the injury done by the larva becomes sufficient to arrest its development. In many cases of this kind the larva works its way up into the corolla and falls with it when it is shed, leaving the young boll quite untouched. Occasionally the flower opens and fertilization is accomplished before any injury is done the pistil, and in rare cases a perfect boll results from an infested square. Sometimes the larva when small works its way down into the ovary before the bloom falls, and in such cases the small boll falls as would a square. (See Pl. VI, *a*, *b*, *d*.)

In large bolls the larvæ feed principally upon the seed and to some extent upon the immature fiber. A larva will usually destroy only one lock in a boll, though two are sometimes injured. When the infestation is severe a number of weevils, occasionally as many as six or even more, may be developed in a single boll, which is completely destroyed by the feeding of the larvæ. (See Pl. VII, *a*, *c*.)

GROWTH.

The rate of growth, of course, is dependent upon many external conditions. It has been found that in squares during the hot weather, the length of the body increases quite regularly by about 1 mm. a day. Full grown larvæ vary in length from 5 to 10 mm. across the tips of the curve. Larvæ of normal size in squares average from 6 to 7 mm. The largest larvæ are developed in bolls which grow to maturity.

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[1] From Bulletin 51, Bureau of Entomology, p. 49.

MOLTS.

To accommodate the rapid growth of the larvæ two or three molts occur. The first occurs at about the second day, and the second at about the fourth day. Whether a third molt occurs before pupation can not be positively stated, but having occasionally found larvæ which had certainly just molted, but which were not larger than the usual size of the second molt, we are led to suspect that three larval molts may sometimes occur, though possibly not always. In bolls where the length of the larval stage is often three or four times as great as that usually passed in squares, it seems almost certain that more than two larval molts occur regularly.

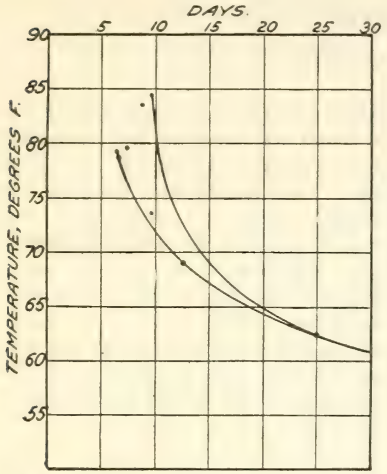

FIG. 9.—Diagram illustrating relationship of temperature to larval period of the boll weevil and showing range due to humidity. (Original.)

According to Dr. Hinds's observations the skin splits along the back, starting at the neck, and is then pushed downward and backward along the venter of the larva. The cast head shield remains attached to the rest of the skin.

DURATION OF LARVAL STAGE.

The length of the larval stage, as a rule, is about equal to the sum of that of the egg and pupal stages. It lengthens as the temperature falls and also as the amount of moisture decreases. It is also probably influenced by the nature and condition of the food supply. These influences will be discussed more fully under the subject of developmental period, as more data are available for the entire period than for any of the stages in this period.

The observations which have been made upon the duration of the larval stage are tabulated and charted below (Table XXIV and fig. 9).

TABLE XXIV.—*Duration of the larval stage of the boll weevil.*

Place.	Year.	Hatched.	Pupated.	Number of larvæ.	Total number of larva days.	Average larval period.	Mean temperature.
						Days.	°*F.*
Victoria, Tex.	1902	Sept. 6	Oct. 5	195	1,462.5	7.5	78.7
Do	1902	Sept. 26	Oct. 21	15	142.5	9.5	73.6
Do	1902	Nov. 11	Dec. 12	15	375.0	25.0	62.5
Victoria, Tex. (ice box)	1904	Aug. 26–Sept. 3		88	1,100.0	12.5	69.0
Alexandria, La.	1907	Aug. 26–Sept. 5	Aug. 28–Sept. 7	149	1,096.0	7.3	79.9
Dallas, Tex.	1908	July 18–29.	Aug. 1–12	50	435.5	8.7	83.7
Do	1908	Aug. 3–19	Aug. 17–31	44	390.0	8.8	84.1
Tallulah, La.	1910	June 27–July 7	July 7–17	98	618.5	[1] 6.3	79.1
Total		June 27–Nov. 11	July 7–Dec. 12	654	5,620.0	8.5	76.2

[1] The extremes were 5.2 and 7.3 days.

PUPAL CELLS.

As the larva becomes larger it gradually forms about itself a hardened black cell, composed of its cast skins and excrement. This cell is of a very tough leathery nature and seems to hold its moisture for a considerable period. In bolls the cell is even harder, as it becomes more or less mixed with lint and attains a considerable firmness, which often gives the cell the hardness and appearance of a seed. These pupal cells frequently include a portion of the hull of a seed, and it has also been found that the larva sometimes forms its cell within a single cotton seed. In these cells the larva transforms to the pupal stage. (See Pl. IX.)

PUPATION.

The formation of the adult appendages has progressed considerably before the last larval skin is cast. The wing pads appear to be nearly one-half their ultimate size. The formation of the legs is also distinctly marked, and the old head shield appears to be pushed down upon the ventral side of the thorax by the gradual elongation of the developing proboscis. Finally, the tension becomes so great that the tightly stretched skin is ruptured over the vertex of the head, and it is then gradually cast off, revealing the delicate white pupa. The cast skin frequently remains for some time attached to the tip of the abdomen. The actual period of ecdysis is about 45 minutes.

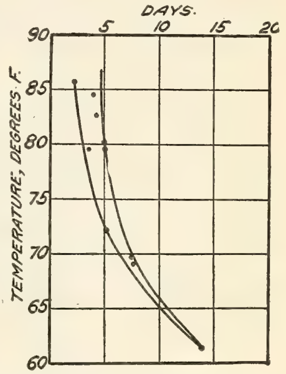

FIG. 10.—Diagram illustrating relationship between temperature and the pupal period of the boll weevil and showing variations due to humidity. (Original.)

THE PUPA.

ACTIVITY.

The pupal stage of the boll weevil is more or less an active stage. The pupa is so constructed, with a forked prong at the posterior tip and with two strong tubercles on the thorax, as to have an axis upon which it can revolve without injuring its more delicate appendages. As the cell is almost round, this movement of the pupa is more or less free in all directions and tends to make the cell harder and more durable. A person with acute hearing can detect the presence of a pupa by holding a square close to the ear. (See Pl. VI, *c*, *d*.)

DURATION OF THE PUPAL STAGE.

In general, it may be said that the length of the pupal stage is about equal to that of the larval stage minus the length of the egg stage. This stage varies considerably, as do the two previous stages, the range being from 2 days at high temperature to 14 or more days at low temperature. During the winter it may be as long as several months. Table XXV and figure 10 are presented to illustrate the variations in the pupal period in their relationship to mean temperature. It may be stated briefly that the length of the pupal stage increases as the temperature decreases, and that the average humidity also influences the stage in the same manner.

TABLE XXV.—*Duration of the pupal stage of the boll weevil.*

Place.	Year.	Pupated.	Emerged.	Number of pupæ	Total number of pupa days.	Average pupal period.	Mean temperature.
							Degrees F.
Victoria, Tex	1902	July 6–13	July 10–16	27	97	3.5	82.65
Do	do	July 12–18	July 16–22	22	84	3.8	
Do	do	July 18–23	July 23–28	86	392	4.5	
Do	do	July 24–25	July 29–30	23	111	4.8	
Do	do	Sept. 15	Sept. 20	4	20	5	79.05
Do	do	Oct. 21–24	Oct. 27–28	5	24	4.8	....
Do	do	Nov. 2–6	Nov. 9–13	29	212	7.3	69.2
Do	do	Dec. 2–13	Dec. 15–29	4	56	14	61.55
Victoria, Tex., ice box	do	....	....	88	660	7.5	69
Dallas, Tex	1907	June 13	June 19	1	5	5	80.1
Alexandria, La	do	Aug. 5	Aug. 7–8	20	43	2.1	85.7
Do	do	Sept. 10–13	Sept. 16–18	141	717	5	72.1
Dallas, Tex	1908	Aug. 1–6	Aug. 5–11	10	41	4.1	84.5
Tallulah, La	1910	July 7–17	July 14–21	50	167.5	[1] 3.3	79.1
Total	1902–1910.	June 13–Dec. 13	June 19–Dec. 29.	510	2,629.5	5.1	74.3

[1] The extremes were 2.8 and 3.9 days.

PERCENTAGE OF WEEVILS DEVELOPED FROM INFESTED SQUARES.[1]

During the season of 1902 part of the many squares gathered in infested fields for the rearing of weevils were followed to learn something of the percentage which produced normal adults. No examination was made for those not yielding a weevil. The decay of the square during the period from its falling to the maximum time that must be allowed for weevils to escape normally so obliterates any small amount of work by a larva that it is difficult, even with examination, to determine accurately the number of dead small larvæ.

TABLE XXVI.—*Percentage of boll weevils from infested squares.*

Locality.	Approximate date.	Number of squares.	Number of weevils.	Percentage of squares producing weevils.
	1902.			
Victoria, Tex	July to August	1,125	360	32.0
Guadalupe, Tex	August	387	108	28.0
	1903.			
Victoria, Tex	June	334	106	32.0
Do	June to August	873	355	41.0
Do	August to September	368	192	52.0
	1904.			
Do	June to September	951	469	49.3
Total		4,038	1,590	39.4

It seems safe to conclude that throughout the season fully one-third of the squares which fall after receiving weevil injury may be expected to produce weevils.

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[1] From Bul. 51, Bureau of Entomology, p. 92.

LIFE CYCLE.

DURATION OF LIFE CYCLE.

We have shown that the average duration of the egg stage under different conditions is 3.7 days, of the larva 8.5 days, of the pupa 5.1 days, of the preoviposition period 7.7 days, and of the oviposition period 31 days. Consequently, the average time from the deposition of the egg to the completion of oviposition by the resulting adult is 56 days. The average required for the combined egg, larval, and pupal stages is 17.3 days. The larva requires about 2½ times as many days as the egg, and the pupa about two-thirds of the time required for the development of the larva.

SEXUAL VARIATIONS.

There are several factors which govern the duration of the life cycle of the weevil. The factor which is of least importance, if, indeed, it is of any importance, is that of sex. Mr. R. A. Cushman, in experiments at Tallulah, La., in 1910, in which squares were under more or less uniform climatic conditions, found that 475 males averaged in development 13.88 days, while 393 females averaged 13.49 days. The figures are so nearly equal that there is great doubt as to whether the sexes require different periods.

VARIATIONS DUE TO LOCATION OF DEVELOPING STAGE.

As has been stated, the tendency of the squares to hang or fall is a determining factor in the length of the developmental stage. In a humid region, however, the difference may be very small. At Alexandria, La., in 1907, it was found that the average developmental period during the first 19 days of August in fallen squares was 15.3 days and in hanging squares was 15.1 days.

VARIATIONS DUE TO TIME OF FALLING OF INFESTED SQUARES.

The period preceding the falling of the squares to the ground seems to be one of the strongest factors in determining the length of the developmental stages. To illustrate this, at Victoria, Tex., in August, 1904, it was found that the average development in squares which hung only 1 day was 13 days, whereas for squares which hung 18 days, the development was 28½ days; also at Dallas, Tex., in August, 1906, the average development in squares which hung 6 days was 19 days and in squares which hung 22 days was 36 days. We present Table XXVII, which shows in general that the difference in the time required for development in hanging and in fallen squares is proportionately the same in all months of the year and at all places where observations have been made.

TABLE XXVII.—*Table to illustrate the effect of the time of falling upon the period of development of the boll weevil in squares.*

No. of days before falling.	Average period of development of weevils for eggs laid during specified periods.												
	Victoria, Tex., 1904.					Dallas, Tex., 1905.			Dallas, Tex., 1906.				Alexandria, La., 1907.
	June.	July 1-15.	July 15-30.	Aug. 2-11.	Sept. 10-29.	Aug. 12-28.	Sept. 11-30.	Oct. 2-3.	June 14-21.	June29-July 6.	July 16-21.	Aug. 12-17.	July 28-Aug. 19.
	Days.	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*	*Days.*
1		12.0		13.0	15.0			25.0					12.5
2		13.5	13.0		13.0	13.2	18.5						12.6
3	14.4	14.0				13.4	21.7		14.5		17.0		12.3
4	14.0	14.4		16.0	15.0	14.5			16.0		15.0		13.5
5	16.0	14.1	14.8		18.0	14.7	18.7	18.0	16.3		17.0		14.9
6	18.0	15.6	17.0	15.0	19.0	16.0		26.0		17.5	17.0	19.0	14.9
7	16.6	15.5	16.0	16.6	16.6	16.6	21.2		16.3	16.0	16.9	17.9	15.0
8	17.6	18.9	17.5		18.6	16.6	28.0		17.0	16.0	17.6	19.5	16.4
9	18.6	18.3		19.6	19.5	19.0			16.0	18.5	18.7	19.5	18.9
10	30.0	18.7		25.2	22.3	19.7					18.6	21.4	17.6
11	17.0	18.8	20.6	21.5	25.5				18.6	24.0	19.2	23.4	21.2
12	23.0	20.8	21.6	22.1	22.0	19.5	28.0				18.1	24.0	
13	19.5	20.0	22.0	25.2	22.5				23.0		19.0	25.0	
14	20.0		19.0	26.1							20.5	24.8	18.0
15		22.0	24.0	23.7					23.0		19.0	25.0	
16		23.0	23.0	28.5							20.0		
17			22.0			25.0		25.0					
18				28.5	24.0							35.0	
19											29.0	36.0	
20													
21												35.0	
22				26.0								36.0	
Average	17.5	16.8	18.8	22.0	18.8	16.2	21.0	23.5	18.0	18.3	18.3	22.3	15.3
No. of stages	36	123	25	62	58	69	17	4	20	9	69	85	87

The average for the 664 stages covered in the table is 18.4 days, which may be taken as the general average period of development in squares. Figure 11 graphically illustrates Table XXVII.

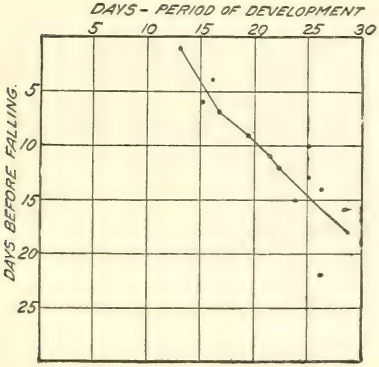

FIG. 11.—Diagram illustrating effect of time of falling of infested squares upon period of development of boll weevil at Victoria, Tex., August, 1904. (Original.)

VARIATIONS DUE TO TEMPERATURE.

It will be noticed that the average period of development in squares which have hung on the plant for the same length of time varies with the season, but an increase of temperature regularly lowers the average developmental period. The following diagram (fig. 12) has been constructed from the average curves determined for each of the stages in the development and shows that the range is from 13 days at 88° F. to 51 days at 62° F.

By using the quantities determined by the curves in figure 12 it is possible to chart the mean or normal developmental period by months for any given place with known mean temperatures. This has been done on the following diagram (fig. 13) for Victoria, Tex., Ardmore, Okla., and Vicksburg, Miss. The curve obtained for Victoria is the widest which can be obtained in the United States with the exception of Texas points to the south of Victoria. It is interesting, however, that

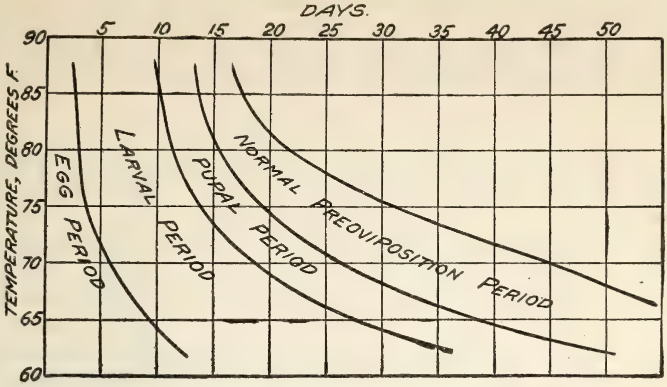

FIG. 12.—Diagram illustrating temperature control of developmental period of the boll weevil. (Original.)

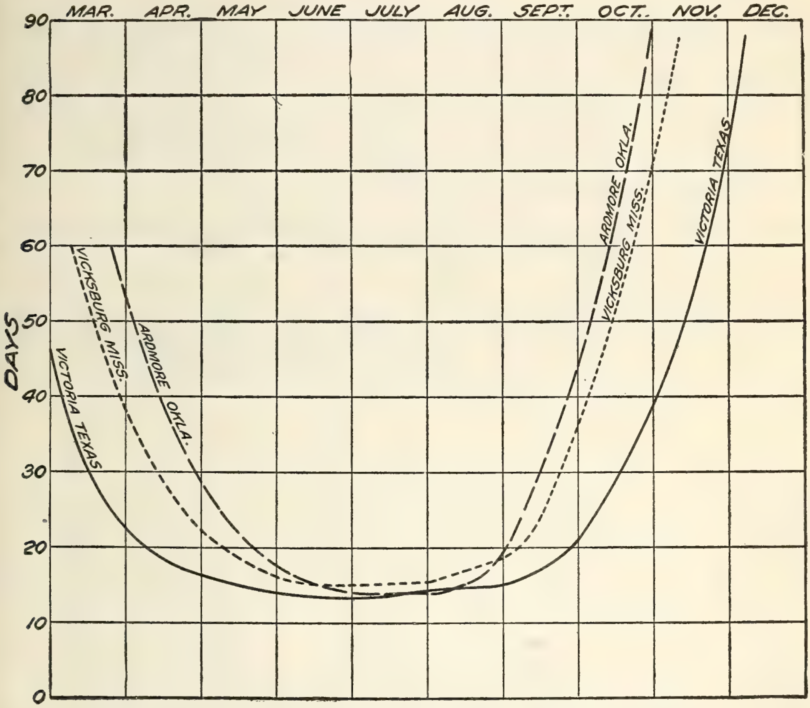

FIG. 13.—Diagram illustrating normal developmental period of boll weevil in squares, by months, at Victoria, Tex., Ardmore, Okla., and Vicksburg, Miss. (Original.)

Pensacola, Fla., would show almost as wide a curve, but there the weevil would show less rapid development in the hottest months. The Memphis, Tenn., curve is slightly wider than that for Ardmore, Okla., and Dallas corresponds almost exactly with Vicksburg. It is interesting to note that Ardmore shows only four and one-half months in which the developmental period can be under 30 days. Adding the preoviposition period to the developmental period, it is evident that unless the weevil adapts itself to the northern conditions latitudes north of Ardmore can have only a fraction over three generations in a year, whereas Victoria, with seven months in which the developmental period is less than 30 days, frequently has six generations.

VARIATIONS OF DEVELOPMENT IN BOLLS.

It is of interest to note the variation in development in bolls due to the length of time the boll hangs on the plant. At Victoria, Tex., in June the development was 15 days for a boll hanging 1 day and 39 days for a boll hanging 26 days, while in bolls which did not drop, it frequently took over 60 days, with 67 as the maximum. The average developmental period of 67 weevils at Victoria and Dallas was 41 days, or more than twice the average period of weevils in squares. This difference may be considered as due to a combination of the factors of lower temperature, greater humidity, and less nutritious food.

MISCELLANEOUS VARIATIONS.

There are also some variations in development which can not be attributed to any of the causes cited above. Undoubtedly the insect adapts itself to the supply and condition of the food available. Consequently, under the same climatic conditions weevils in very small or delayed squares develop more quickly than those where the food is more suitable. Such variations are illustrated by Table XXVIII, which relates to the developmental periods of weevils of the third generation at Alexandria, La., in 1907.

TABLE XXVIII.—*Table showing variations in the developmental period of boll weevils in the third generation at Alexandria, La., in 1907.*

Date of oviposition.	Number of stages.	Total egg days.	Average egg period.	Total larva days.	Average larval period.	Total pupa days.	Average pupal period.	Total weevil days.	Average total period.
September 2	1	1	1	....	....	....	....	....	....
Do	4	4	1	24	6	....	....	....	....
Do	7	7	1	42	6	28	4	77	11
Do	4	4	1	28	7	....	....	....	....
Do	7	7	1	49	7	28	4	84	12
September 1–4	54	108	2	....	....	....	....	....	....
September 1	1	2	2	7	7	3	3	12	12
September 4	3	3	1	24	8	12	4	39	13
September 5	2	4	2	....	....	....	....	26	13
September 3	2	4	2	10	5	12	6	26	13
September 4–5	10	20	2	60	6	50	5	130	13
September 1–5	30	60	2	210	7	120	4	390	13
September 2	5	5	1	20	4	45	9	70	14
Do	16	16	1	112	7	96	6	224	14
Do	4	4	1	40	10	16	4	56	14
Do	12	24	2	72	6	72	6	168	14
September 3–4	3	6	2	21	7	15	5	42	14
September 2–4	18	36	2	144	8	72	4	258	14
September 2	9	18	2	81	9	27	3	126	14
August 31	14	42	3	....	....	....	....	....	....
Do	3	9	3	....	....	....	....	42	14
Do	3	9	3	24	8	24	3	42	14
September 1	2	4	2	14	7	12	6	30	15
August 31	4	12	3	32	8	16	4	60	15
September 1	6	12	2	42	7	42	7	96	16
August 31	2	6	3	16	8	10	5	32	16
Do	3	9	3	24	8	18	6	51	17
August 26	3	....	....	....	....	....	....	57	19
Do	3	....	....	....	....	....	....	60	20

TABLE XXVIII.—*Table showing variations in the developmental period of boll weevils in the third generation at Alexandria, La., in 1907*—Continued.

TOTALS AND AVERAGES.

Date of oviposition.	Number of stages.	Total egg days.	Average egg period.	Total larva days.	Average larvel period.	Total pupa days.	Average pupal period.	Total weevil days.	Average total period.
Egg period	229	436	1.9	....	....	....	....	....	....
Larval period	149	....	....	1,096	7.3	....	....	....	....
Pupal period	141	....	....	....	....	717	5.0	....	....
Total period	152	....	....	....	....	....	....	2,198	14.4

DEVELOPMENT OF WEEVILS IN THE SQUARES WHICH NEVER FALL.

It is generally true that squares seriously injured by the weevil sooner or later fall to the ground. The form of the absciss-layer grown when the square is injured determines whether it is to fall or to hang. (See Pl. XV.) This will be explained fully in connection with the discussion of parasites (pp. 143, 144).

Certain climatic and cultural conditions seem to increase the tendency of the cotton plants to retain the infested squares, although this tendency seems to be very largely of a varietal character. In the hanging position the square dries thoroughly and becomes of a dark-brown color. Although exposed to complete drying and the direct rays of the sun, the larvæ within are not destroyed by the sun in the same proportion as those which are exposed to the sun on the hot soil. However, control by parasites is much greater in the hanging squares than in the fallen squares—so much greater at times that the total mortality from all causes in hanging squares surpasses that of fallen squares. This matter will be dealt with more fully in a later section.

Owing to the much smaller number of squares which hang on the plants, we have been unable to obtain a sufficiently large series of records upon the development of the weevil in this class of squares, but the records available show that the development is slightly shorter in hanging squares than in the average fallen squares.

DEVELOPMENT DURING WINTER.

As is normal with many species of weevils, there is some development during the winter months. This development, however, is frequently cut short by severe freezes. In southern Texas larvæ and pupæ of the boll weevil which are in squares when frost comes are not always killed thereby, but slowly finish their development if the weather is warm enough for any activity, and the adults thus developed may live through the winter without feeding. Mr. J. D. Mitchell took a number of live larvæ, pupæ, and adults from bolls in a field at Victoria, Tex., on December 26, 1903, after two hard frosts and one freeze. Two weeks later, from a field in the same locality, after three hard frosts and two freezes (30° F.), he took another lot of live specimens in these three stages. On February 7, 1904, Mr. Mitchell took 32 adults, 1 pupa, and 4 larvæ, all alive, from standing stalks, and on February 14 he found 32 adults, 2 pupæ, and no larvæ. The material collected at different times up to February 14 included 197 specimens, 23 larvæ, 30 pupæ, and 144 adults. It is therefore evident that large numbers of weevils go into the winter in the immature stages, and there is every probability that, in the southern part of Texas at least, many of them live and mature, emerging in the spring. It may be that this gradual maturity of the hibernated weevils is one of the reasons why they emerge so irregularly from their winter quarters.

Prof. Sanderson, in Bulletin 63 of the Bureau of Entomology, mentions that in March, 1903, Mr. W. P. Allgood sent him from Devine, Medina County, Tex., a quantity of bolls, which were examined March 12. Twenty per cent of the bolls contained weevils, alive or dead, in some stage. In 40 bolls there were 40 live and 11 dead pupæ, 30 live and 40 dead adults, and 5 dead larvæ. Many of the adults had just transformed from pupæ. One live larva was found in the material. Estimating the survival of weevils in the plants in this field, Prof. Sanderson calculated that there would be about 10,500 weevils per acre in the spring. The lowest temperature which the weevils experienced in the locality from which these bolls were sent was 23° F. in February.

SEASONAL ABUNDANCE.

BROODS OR GENERATIONS.[1]

The term "brood" can hardly be applied in its usual sense to the generations of the weevil, as was pointed out by Dr. L. O. Howard in the first circulars of the bureau dealing with the problem. For several reasons no line of distinction can be drawn between the generations in the field at any season of the year, not even between hibernated weevils and the adults of the first generation. As has been shown, the period of oviposition among hibernated females is in some cases fully 3 months, while it averages 48 days. The average period of the full life cycle for the first generation is 25 days, and as the time for the second generation would be slightly less, it is evident that the first eggs for the third generation may be deposited at the same time as those for the middle of the second generation, and also with the very last of the eggs deposited by hibernated females for the first generation, as shown in figure 14. The great overlapping of generations thus produced prohibits the application of any of the common methods of ascertaining their limits. The complexity indicated for the first three generations becomes still further increased as the season advances, so that in October, for example, a weevil taken in the field might possibly belong to any one of five or six generations. Duration of life and the period of reproductive activity are important factors in determining the average number of generations. Periods of greatest abundance can not be regarded as giving any reliable information upon this point, since the number of weevils developed soon comes to depend largely upon the supply of squares.

In the case of the boll weevil, therefore, the information upon the number of generations must be drawn mainly from laboratory sources, but the results are supported by observations made in the field. Many of the hibernated weevils continue to deposit eggs until the middle of July, and some are active for fully a month longer. In 1903 the last eggs from hibernated weevils were deposited on August 27. In the course of rearing experiments made in 1902 it was found that many weevils which had become adult about the 1st of August would continue to deposit eggs until the latter part of November. Considering the longest-lived weevils and their last-laid eggs, therefore, it is easily possible for two generations to span the entire year. The weevils developing after the middle of November may go into hibernation, and from their last deposited eggs produce weevils whose last offspring will be ready for successful hibernation again. This conclusion is based upon actual demonstration.

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[1] The following two paragraphs are taken from Bull. 51, Bureau of Entomology, pp. 95, 96.

The maximum number of generations will be found by taking the first instead of the last eggs deposited in each case. In order to ascertain the maximum number of generations which would be possible, the figures for the development at Victoria, Tex., have been taken. Figure 14 is a diagram which shows the maximum number of generations possible and also the minimum number possible. This is based upon the mean temperatures of the various months at Victoria and the known period of development at such mean temperatures. The maximum number of generations of course begins with the first egg laid by the first weevil to begin oviposition in the spring and continues with the first egg of the first developing weevil from each generation. In this manner it will be seen that 10 generations are possible for weevils reared on squares. The last egg laid by the first emerged weevil and the last eggs laid by the following generations allow only three generations from the first emerged weevils, which might be considered the minimum. The maximum number of generations from the last emerging weevils by the same system can only be eight generations, whereas the minimum number of generations from the last emerged weevils will be two generations.

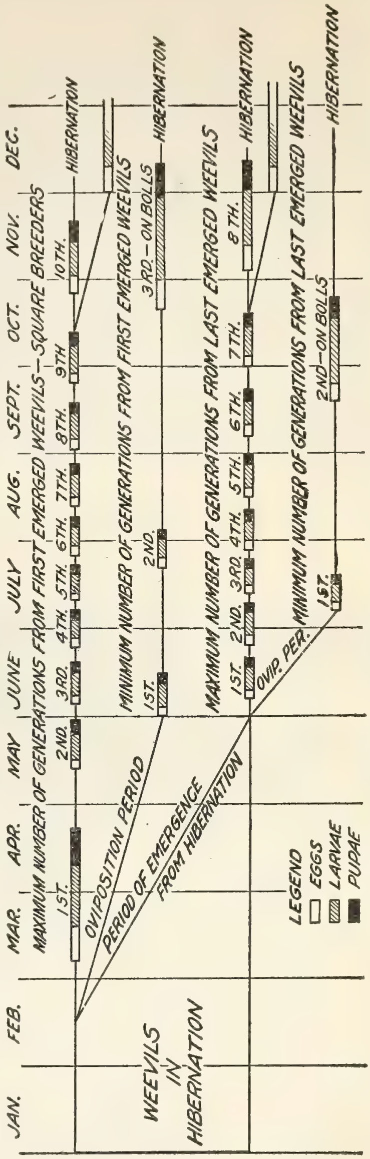

FIG. 14.—Diagram illustrating seasonal history of the boll weevil at Victoria, Tex. (Original.)

There is no basis for the idea that there is a distinct hibernation brood. The activity of the adults and the development of the immature stages is gradually retarded by the decline in temperature until hibernation time arrives. Most of the weevils of the first two or three generations have probably died, or then do so, while most of the adults of later generations, still having considerable vitality, go into hibernation. It is certain that every generation may have some direct part in the production of weevils which are to hibernate. All weevils which are still strong and healthy when cold weather comes on may be expected to go into hibernation, so that there can be no special brood for this purpose.

POSSIBLE ANNUAL PROGENY OF ONE PAIR OF HIBERNATED WEEVILS.

One of the most important factors in the development of an insect is its capacity for very rapid production. The conclusions as to the ability of the boll weevil in this respect are drawn from the following data, summarized from what has been set forth in preceding pages of this bulletin. The starting point is considered to be the average date of deposition of one-half of the eggs for the first generation at Victoria, Tex., which, under the usual conditions, seems to be about June 10. The average number of eggs deposited by a female was found to be 139. For the purpose of this computation 70 is the assumed number. The difference may be considered as an allowance for mortality or failure to hatch. The average period of development for each generation is 19 days. The average period between emergence of the adult and deposition of the first eggs is 6 days. The average period for the deposition of one-half the eggs for each generation is 18 days, thus making the average period for each generation 43 days. The sexes are produced in approximately equal numbers. For the sake of conservatism allowance has been made for only four generations in a season. The following table shows the rate of multiplication and the corresponding dates:

Annual progeny of one pair of hibernated weevils.

	Weevils.
First generation, average adult June 29, numbering	70
Second generation, average adult Aug. 10, numbering	2,450
Third generation, average adult Sept. 22, numbering	85,750
Fourth generation, average adult Nov. 4, numbering	3,001,250
Total	3,089,520

As a matter of fact, the multiplication during the early part of the season is so much more rapid that it is very certain that a large part of the third generation becomes adult by the middle of August. Possibly a more definite idea of the significance of this ability for reproduction may be obtained if we consider that, at the conservative rate given, the progeny from one fertile hibernated female might, in the course of four generations, number one weevil for every square foot of area in a 75-acre field.

As a matter of fact, the possibility of the multiplication is controlled primarily by the abundance of food supply. The maximum infestation is usually reached some time in August. If we assume that there are 6,000 plants on each acre of ground, and that each plant produces 100 squares for weevil attack up to August 1, we would find that if the usual percentage of these squares produces weevils, the actual

Fig. a.—Newly planted cotton field, with sprouts from overwintered cotton roots. (Original.)

Fig. b.—Fallen infested squares. (Original.)

FIELD CONDITIONS IN TERRITORY OCCUPIED BY THE BOLL WEEVIL.

multiplication would be limited to about 250,000 weevils per acre. It has been shown in this bulletin that on the average over 50 per cent of the weevil stages are destroyed by natural conditions. This means that the theoretical possibilities are never reached. In fact, it is doubtful whether the actual increase from a single pair exceeds 2,000,000.

Prof. Sanderson, in Bulletin 63, of this bureau, estimated that the actual increase in the number of weevils from the 1st of June to the 1st of September is about 50 times and certainly not over 65 times, where theoretically it would be 625 times.

PROGRESS OF INFESTATION IN FIELDS.

It is of considerable importance to understand the rate of increase of the infestation in the fields. Normally, in a given cotton field the infestation when the squares have just begun to form is under 10 per cent, but this percentage increases very rapidly in proportion as the hibernation was successful. The infestation generally starts in a given field in the vicinity of timber or of buildings where cotton or cottonseed was stored during the winter. It then progresses in increasing circles until the entire field is scatteringly infested. From then on the increase is general until it is almost impossible to find an uninfested square. Table XXIX may be used to illustrate the progress of infestation in a given field.

TABLE XXIX.—*Progress of infestation by the boll weevil, field 1, Victoria, Tex.*[1]

Block.	Date.	Number of squares examined.	Number of squares infested.	Percentage.	Remarks.
	1903.				
I	June 8, 9	4,200	675	16.0	Work of hibernated weevils only.
	July 13	467	211	45.0	Second generation at work.
	July 22	249	193	77.5	Third generation beginning.
	August 4	278	224	80.6	
	August 29	91	85	93.5	About four generations now working.
II	July 30	358	168	46.6	Much cotton dying from root rot.
	August 1	331	148	44.7	
	August 4	300	100	33.3	
	August 20	699	636	91.1	
	Total	6,973	2,440	35.0	

[1] From Bull. 51, Bureau of Entomology, p. 114.

Additional illustrations are furnished in Table XXX.

TABLE XXX.—*Observations upon infestation by the boll weevil, various localities, 1904.*[1]

Locality (Texas).	Number of plots under examination.	Number of examinations made.	Period covered.	Total squares examined.	Average percentage of squares showing weevil attack.	Total number of weevils taken with squares.	Average percentage of squares containing weevils.	Total number of small bolls examined.	Average percentage of small bolls attacked by weevils.	Average percentage of squares showing attacks by other insects.	Average percentage of clean squares.
Calvert	12	2	1904. Aug. 23 to Sept 9.	2,754	94.0	251	9.1	1,175	94.7	1.8	4.2
Corsicana:											
A	12	5	July 29 to Sept. 12.	6,951	72.4	376	5.7	2,506	71.9	.6	27.0
B	11	5	July 28 to Sept. 12.	4,534	80.4	407	9.0	3,261	64.9	.6	19.0
Mexia	15	5	July 30 to Sept. 13.	6,445	64.4	317	5.0	4,618	64.9	1.2	34.5
Palestine	22	2	Aug. 26 to Sept. 14.	3,719	91.3	274	7.4	2,456	92.8	.7	8.2
Victoria	11	18	June 18 to Sept. 24.	13,227	54.2	170	1.3	544	66.9	6.1	44.6
Wharton	4	4	July 22 to Aug. 25.	5,005	65.0	167	3.3	230	46.4	10.2	25.3
Total	87	......	June 18 to Sept. 24.	42,635	......	1,962	......	14,790	......	......	......
Average	......	6	....	....	70.1	......	4.6	....	80.0	2.2	27.7

[1] From Bull. 51, Bureau of Entomology, p. 116.

Prof. Sanderson[1] has estimated that usually 50 per cent of the squares will be punctured by about two months after the cotton commences to square, at which time there would normally be about 100 squares to the stalk. When one-half of the squares are punctured it may be readily concluded that there are probably sufficient weevils present to prevent any more squares from forming fruit. It will be seen, therefore, that the critical period in the relation between natural increase of squares on the plant and increased injury by the boll weevil is during the period of six to eight weeks after the first squaring, which usually coincides more or less closely with the time between the appearance of the second and third broods of the weevils. Thus, if we consider six weeks as the average time for cotton to begin to square after planting, it will be seen that the bulk of the fruit must be set in 85 or 95 days after planting. In other words, to escape injury by the boll weevil, cotton must be so grown that the bolls will commence to open in about 100 days after planting and that all the fruit which will probably be secured must be set within 45 days after the squares begin to form. The advantage of early planted cotton and rapid-maturing varieties becomes, therefore, very apparent.

Field examinations have shown that the period of maximum infestation is reached between August 1 and 20, and that from 6,000 to 10,000 adult weevils per acre is sufficient to cause maximum infestation within a few days. The highest number of weevils per acre which has ever actually been recorded from a locality during the summer was

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[1] Bull. 63, Bureau of Entomology, p. 38.

24,347 adult weevils at Port Gibson, Miss., in August, 1911.[1] With this number of weevils there was a record of only 37.03 per cent infestation of the remaining squares and bolls. Higher percentages of infestation have been recorded with much smaller numbers of adult weevils per acre.

EFFECT OF MAXIMUM INFESTATION UPOM WEEVIL MULTIPLICATION.

At the time of maximum infestation the majority of the third-generation weevils are becoming adult and many of the hibernated weevils have died. About this time also a decrease in square production accompanies the maturity of the bulk of the crop, owing to the fact that the assimilative power of the plant is largely consumed in maturing seed. If dry weather occurs at this period, which is frequently the case in Texas, there is a further decrease in the number of weevils present. Not only are there fewer squares to become infested, but each square is also subjected to greater injury, and many which would otherwise produce weevils are unfitted as food for the larvæ by the decay which follows the numerous punctures. Several eggs may be deposited in each square, but as a rule only one weevil

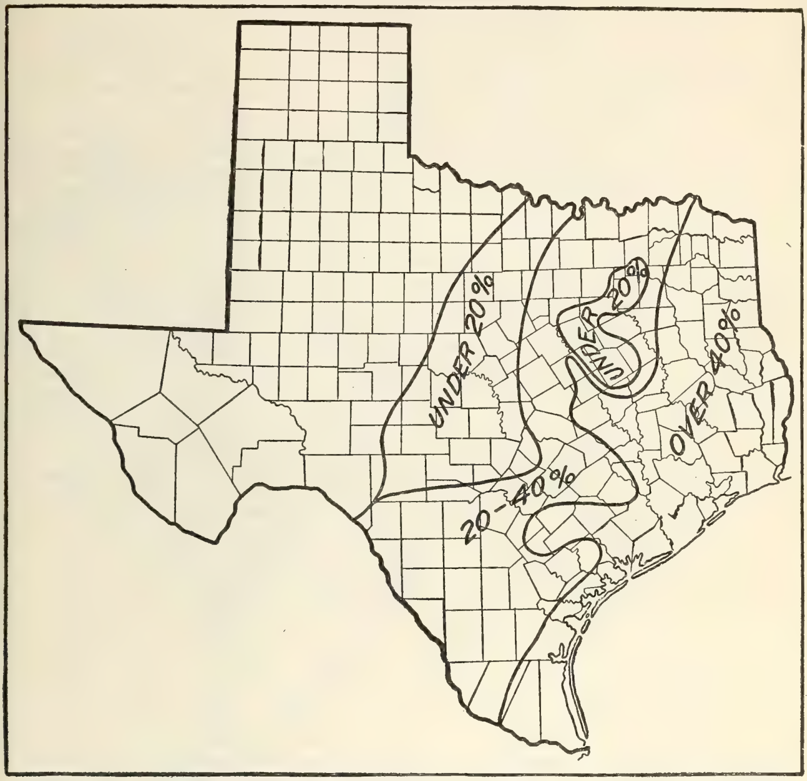

FIG. 15.—Status of the boll weevil in Texas in August, 1906; percentage of infestation of all forms. (Original.)

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[1] During the late fall the number may be much larger. See p. 76.

will develop. These general conditions frequently bring about a reduction of the number of weevils present in the field. This becomes evident to the planter by the number of blooms seen. Of course, the conditions soon change and the weevils become more abundant than before.

STATUS EXAMINATIONS.

In order to become fully acquainted with the conditions of the weevil during the most important parts of the season, it has been the custom to conduct an extensive series of observations in the latter part of June and first part of July and again in the first half of August in order to learn the extent of damage being done by the weevil. These examinations have been made so thoroughly and have been distributed in such a manner that it has been possible, even in June, to determine the probable direction of the greatest movement of the weevil during the season, to point out the regions in which the damage to the crop will be greatest, and also to indicate where the control of the weevil during the winter has been of greatest consequence. The first "status" of the year frequently gives very definite evidence of natural control or an absence of it. While certain general methods of

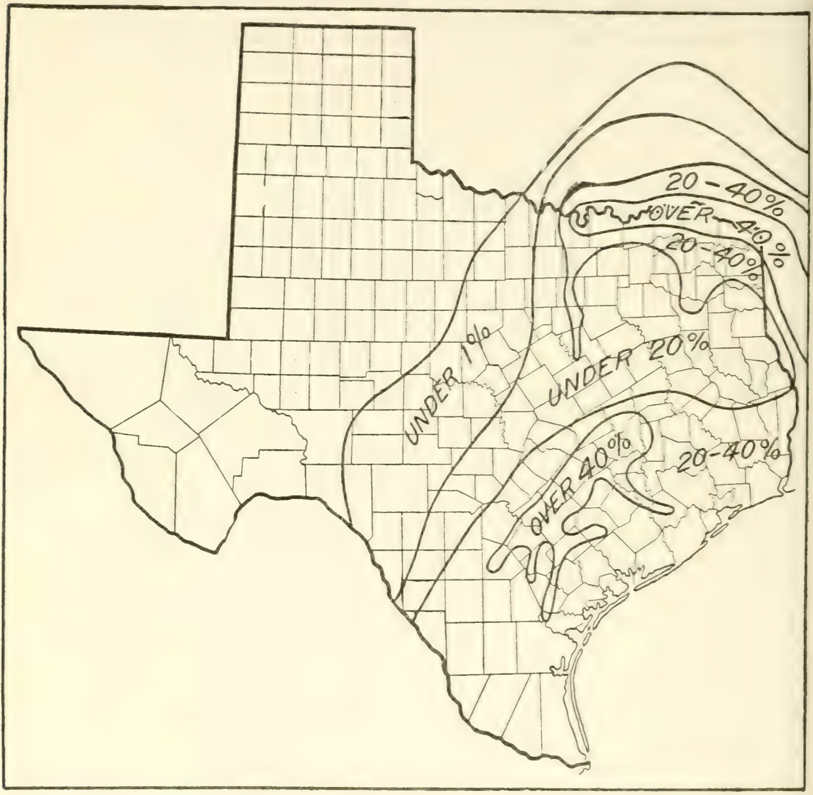

FIG. 16.—Status of the boll weevil in Texas in August, 1908; percentage of infestation of all forms. (Original.)

control have been contrived, it is still true that some of the most important methods of control are those which are devised to suit particular emergencies. These have been indicated from time to time in connection with the status reports.

RELATION OF WEEVILS TO TOP CROP.

After considerable cotton has been matured fall rains often stimulate the production of a large number of squares, and many planters are misled by the hope of gathering a large top crop from this growth. The joints of the plant are short, and the squares are formed rapidly and near together. Though weevils may have been exceedingly numerous in the fields, their numbers will have become so decreased by the dispersion and by the limited quantity of food that they can rarely keep up with the production of squares at this period of rapid growth. Many blooms may appear, and the hope of a large top crop increases. It has been a very rare occurrence that planters have gathered top crops, even in years of no injury from insects.

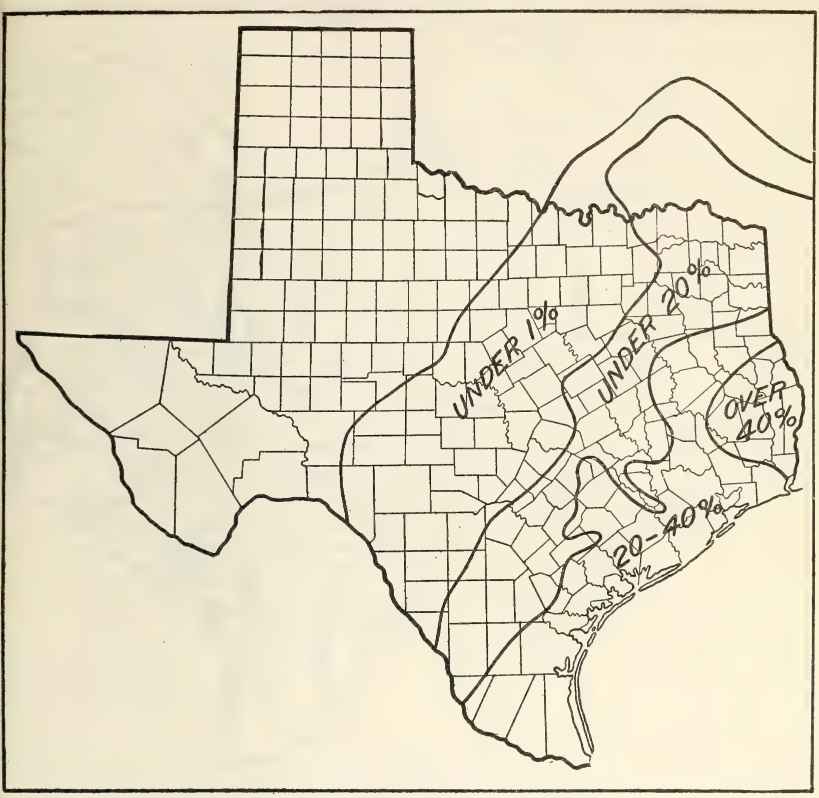

FIG. 17.—Status of the boll weevil in Texas in August, 1909; percentage of infestation of all forms. (Original.)

The chance of its development, though always small, becomes practically inconsiderable wherever the weevil is present in numbers.

In the senior author's experience of 10 years only one example of a top crop in a weevil district has been seen. This happened in the vicinity of Brownsville, Tex., in 1911. The production of a few bolls on the tops of the plants was due to a rare combination of exceptional influences, including very dry weather during the summer, defoliation at an early date by the cotton worm, and late rains after the weevils were greatly reduced in numbers.

Neither the very remote chance of gathering a top crop nor the actual injury which is being done to the crop of the succeeding year by allowing that growth to continue until frost kills it is generally appreciated by planters. Because of the apparent abundance of squares and the presence of many blooms the plants are allowed to stand long after they might have been destroyed to the great benefit of the next crop. As is the case in the early spring, however, the abundance of squares increases greatly the production of weevils, and though a few bolls may set, they are almost certain to become infested before they reach maturity. Every condition, therefore, contributes to the production of an immense number of weevils very late in the season and at just the right time for successful hibernation. As a result, far greater injury is done to the crop of the following

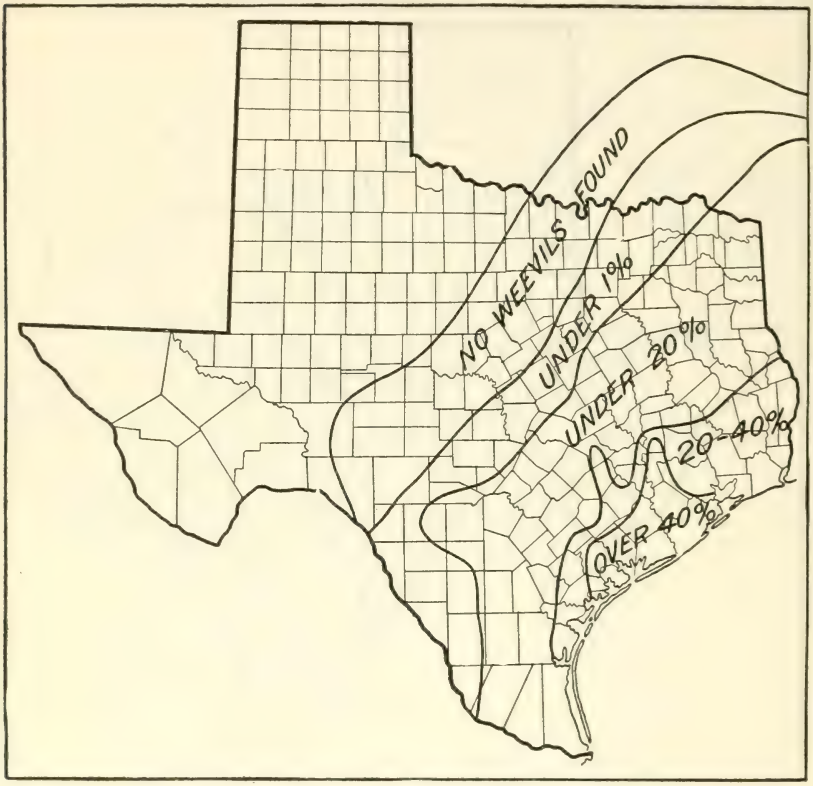

FIG. 18.—Status of the boll weevil in Texas in August, 1910; percentage of infestation of all forms. (Original.)

season with no actual gain in the yield of the current season. Plants standing until frosts kill them are often allowed to remain throughout the remainder of the winter and easily furnish an abundance of favorable hibernating places for the weevils. The consequence of this practice is that so many weevils are carried through the winter alive that the yield of the next year is much less than it might have been but for the farmer's indulgence of the forlorn hope of a top crop. It is far wiser to abandon the uncertain prospects of a top crop and destroy the stalks in order to insure a better crop the following year.

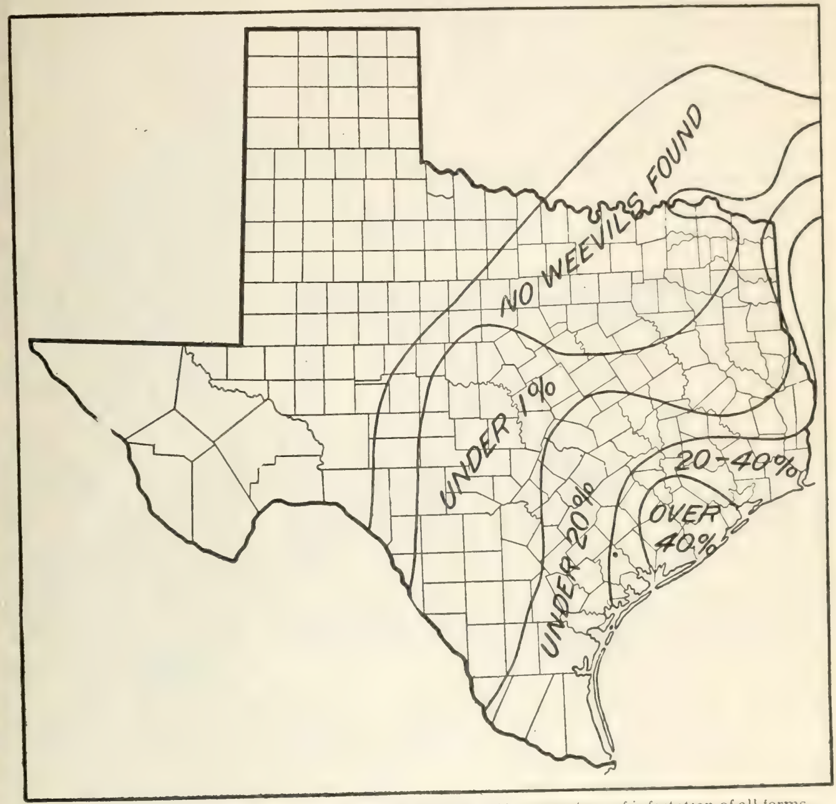

FIG. 19.—Status of the boll weevil in Texas in August, 1911; percentage of infestation of all forms. (Original.)

VARIATIONS IN ABUNDANCE OF THE WEEVIL FROM YEAR TO YEAR.

The decrease in damage by the weevil in Texas in the last few years has led some observers to believe that the insect will finally disappear altogether. Investigation shows that this belief is erroneous. In 1897 the French entomologist, Dr. Paul Marchal, published a paper which set forth some of the essential factors governing insect abundance from year to year. This author called attention to the more or less regular periodicity in the abundance of certain well-known injurious insects. In this country the cotton leaf worm, *Alabama argillacea* Hübner, is an example of such periodical abundance. The application of Dr. Marchal's law to the abundance of the boll weevil will be discussed in the following paragraphs.

When the boll weevil entered the United States, it was released from most of its natural enemies and was in the portion of the cotton belt most resembling its natural home. Naturally, it increased with great rapidity. In fact, the weevil was on what may be called the upward curve of numerical abundance from 1892 to 1896. In the meanwhile, native parasites began to adapt themselves to it, and we may assume that their abundance might be indicated by a curve parallel to but behind that of the boll weevil. In 1896 a severe drought was the cause of a very sudden decrease in the numbers of the weevil and of course also acted upon the parasites. Following 1896 the increase in abundance of the weevil was comparatively slow, owing to the unlimited opportunities for spread. The maximum point in this increase appears to have been reached in the autumn of 1904 and may have been partly due to the fact that in that year the abundance of the parasites was on the decrease. In the winter of 1904 a severe cold period turned the curve of abundance downward, but the decrease was slow until the fall of 1907, when another severe freeze caused a sudden falling off. Floods in the spring of 1908, drought in the summer, a freeze in the fall of the same year, and droughts in the summers of 1909, 1910, and 1911, followed in 1909 and 1910 by severe winters, all combined to reduce the weevil still more. On the other hand, from 1904 to 1908 the influence of the parasites was increasing and from then until 1911 decreasing. As Dr. Marchal pointed out, it is very rare that some condition does not intervene just before the number present has reached zero and save the species from extermination. The weevil will undoubtedly frequently be greatly reduced in large regions, but in such areas the inflow from other localities will serve to bring about early reestablishment. (See fig. 20.)

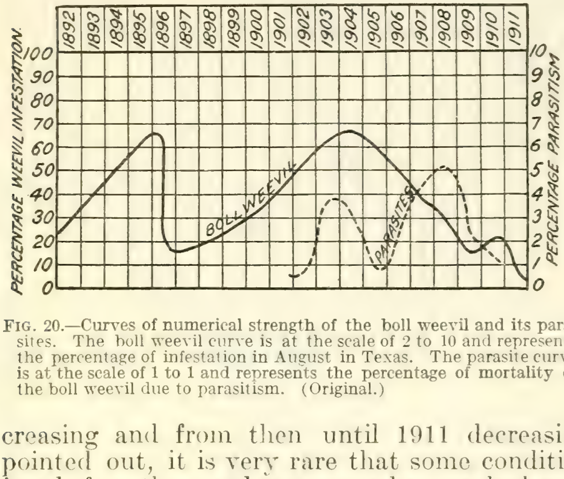

Fig. 20.—Curves of numerical strength of the boll weevil and its parasites. The boll weevil curve is at the scale of 2 to 10 and represents the percentage of infestation in August in Texas. The parasite curve is at the scale of 1 to 1 and represents the percentage of mortality of the boll weevil due to parasitism. (Original.)

Undoubtedly the adverse seasons of recent years will be followed by others which will allow the weevil to reach approximately its former abundance. This alternation of years of scarcity and of abundance will continue indefinitely. Naturally, no definite prediction can be made as to the number of years which will be included in the alternating periods.

The series of Texas maps presented herewith (figs. 15–19) illustrates the variations in the percentage of infestation in August during a series of years in which the weevil abundance was at a low ebb. They also show very plainly how the areas of heavy damage are shifted by more or less local causes.

The status examinations upon which these maps were based show the following average percentages of infestation in Texas. (See Table XXXI.)

TABLE XXXI.—*Percentage of infestation by the boll weevil in Texas in August; years 1906 to 1911.*

Year.	Percentage of infestation.
1906	50. 11
1907	38. 09
1908	32. 32
1909	14. 78
1910	20. 79
1911	1. 12

NATURAL DISSEMINATION.

The natural movements of the boll weevil are of several more or less distinct kinds. For several months in the spring there is a general dispersal in search of food. After the cotton commences to square there is a steady spread across the fields from the vicinity of the places where the insects have hibernated. This may become a spread from field to field. In late summer there is a sudden and wide dispersal, which is shortly followed by a search for hibernation.

SPRING SEARCH FOR COTTON.

After a quiescent period of from five to eight months the weevils leave their hibernation quarters and start in search for food. During a warm period, such as was experienced in March, 1907, many weevils come out of hibernation long before any cotton has made its appearance. Without doubt these weevils wander considerable distances and finally either die or reenter the quiescent state on account of lower temperatures. As the emergence from hibernation covers a period of about three months there is little or no regulation of the direction of flight, such as might occur if all emerged at the same time during a high wind. Elaborate tests have been made by releasing marked weevils fresh from hibernation in the vicinity of cotton fields. Invariably after careful search a very small percentage of these weevils have been found in the nearest cotton.

The experiments of Mr. A. C. Morgan in 1906 at Victoria, Tex., give the most specific data on individual flight. Seven hundred and eleven weevils were used in the experiments, of which 355 had been fed and 356 were unfed. Of the fed weevils 179 were male and 176 female, while of the unfed weevils 183 were male and 173 female. This gave a total of 362 male and 349 female weevils. The maximum flight by a fed male was 775 yards, by a fed female 350 yards, by an unfed male 225 yards, and by an unfed female 500 yards. The experiments also showed the average distance per 24 hours for a fed weevil as 63.3 yards, and for an unfed weevil, 66.6 yards. It was generally observed that the weevils flew with the prevailing wind.

Observations on the early spring movement of the weevil in Mississippi in 1910 showed the utility of the rotation of crops. During the two status examinations made in 1910 in southern Mississippi it was very evident that in these fields in which cotton followed corn there was a conspicuous absence of infestation until the fall dispersion of 1910, whereas in neighboring fields in which cotton followed cotton the infestation was in some cases extremely high, even in June.

These circumstances and many others which have been observed in the spring indicate a rather irregular dispersal from the places of hibernation which may carry the weevils considerable distances in all directions. On the extreme border of the infested territory this may result in the infestation of entirely new territory.

SPRING SPREAD WITHIN THE FIELD.

The spread from plant to plant begins in the portions of the field adjacent to favorable hibernation quarters. It has usually been found that the early summer infestation begins at a point adjacent to timber or near farm buildings where seed or seed cotton has been stored. From these centers it is generally easy to trace the infestation to other parts of the field. The movement of the weevils from these centers, however, is not regular. They occasionally fly to rather distant portions of the field and then start new centers, but on the whole the progress is steady and soon brings about a complete infestation of the field.

A number of observations were made to determine the degree of movement of hibernated weevils in a field at Victoria, Tex., in 1904. The weevils were marked so that they could be recognized, and frequent examinations were made to determine the location of each specimen from day to day.[1] It was found that the maximum time one weevil remained upon a single plant was 18 or more days, the observations having been discontinued after the eighteenth day. The average time positively found in 73 cases was 4 days, with a possibility for this same number of observations of 6⅔ days. Probably a true average lies approximately between these results, and, if so, we may assume that about 5⅓ days usually intervene between the movements of each weevil. In the whole series of observations, extending over 25 days, for weevils which were found after being liberated, only 57 movements were recorded. The total of these movements averaged only 62 feet each in 177 movement days. This would give us an average movement of but 0.35 foot per day for each weevil in a field where stubble plants were quite abundant, where squares were forming upon fully one-third of the plants, and during a period for which the mean average temperature was 78.6° F.

SUMMER FLIGHTS.

During the summer there is more or less general movement within the cotton fields and also from field to field. These flights are at first weak, but gradually become more pronounced and finally lead into the great dispersal of the late summer and fall.

During the summer the conditions on the border of the infested area are peculiar. Many of the weevils which arrived late in the fall of the preceding year are unable to survive the winter on account of their exhausted condition. Therefore, the line of continuous infestation may be considerably behind the line of continuous infestation resulting from the last movement of the preceding year. Outside of this continuous line is a strip of considerable width in which the weevil is found scatteringly. The summer flights cause these isolated infestations to coalesce.

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[1] The remainder of this paragraph is from Bulletin 51, Bureau of Entomology, p. 112.

FALL DISPERSION.

All movement of the weevil at other seasons is insignificant in comparison with the great dispersion of the fall which carries the insect far into new territory. It is this movement which causes the more or less regular annual advance in the cotton belt. In one sense this dispersion is merely an overflow from territory in which the insects have become so numerous that there remain no opportunities for breeding. In another sense it appears to be the result of a strong instinct which the weevils possess to invade new regions. At any rate, they show great activity in the late summer and fall. The main causes of the fall flight, therefore, appear to be (1) a scarcity of food and breeding places due to maximum infestation, and (2) an instinct to invade new territory. Several conditions may tend to precipitate the movement or strengthen it. Among these are damage by other cotton insects, which hastens maximum infestation, and drought, which may have the same effect by preventing the continued fruiting of the plants.

There seems to be no special tendency to fly in any particular direction, although prevailing winds frequently cause the majority of the insects to follow one course. This has been observed to be southeast, north, and east in different localities. If not governed by the wind, any weevil which takes flight is as likely to fly toward the old infested territory as in any other direction. It is, therefore, only a portion of the dispersing weevils which enlarges the infested territory.

The distance any weevil will fly in this movement depends upon how soon it finds uninfested cotton. If on the first flight it finds only heavily infested cotton or none at all it will take wing again. In this way a succession of flights may carry the insect over a wide territory. In one case a distance of over 40 miles has been known to be covered in this manner. If, on the other hand, the first flight carries the weevil into an uninfested field it remains there. Consequently, the advance is slowest in regions where cotton fields are numerous. The occurrence of the leaf worm, *Alabama argillacea*, in great numbers in any locality destroys the food and tends to cause decidedly longer flights of the dispersing weevils.

So far as we have been able to discover, the weevil has no sense by which it can locate cotton. Such a sense may exist, but the general aimless flight of thousands upon thousands of individuals seems sufficient to account for the infestation of all fields in new territory. An interesting observation was made by the junior author and Mr. G. N. Wolcott near Meridian, Miss., that the early dispersing weevils, in flying through hill country with heavy woods, found only the patches on the tops of the hills and from these gradually spread downward to the denser cotton.

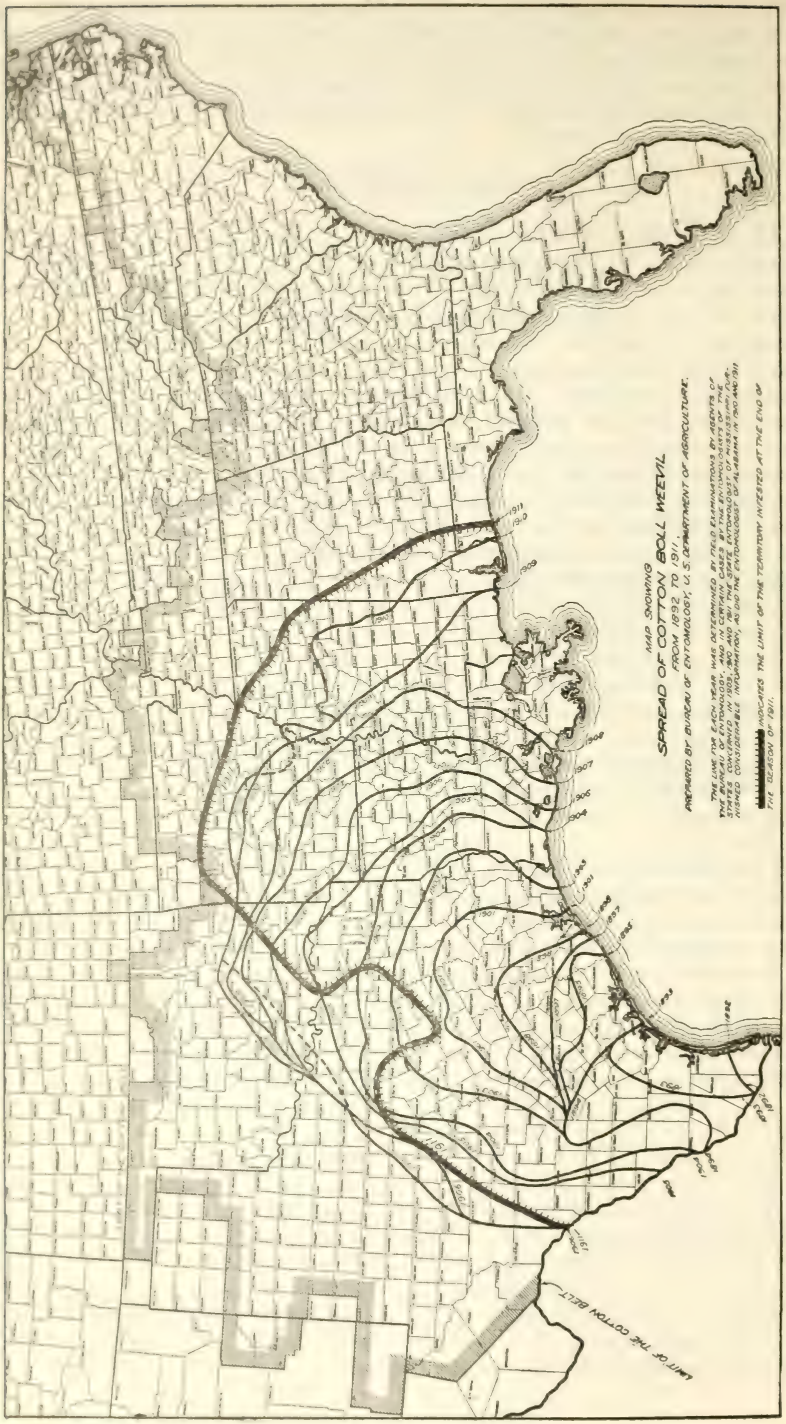
MAP SHOWING
SPREAD OF COTTON BOLL WEEVIL
FROM 1892 TO 1911.
PREPARED BY BUREAU OF ENTOMOLOGY, U. S. DEPARTMENT OF AGRICULTURE.
THE LINE FOR EACH YEAR WAS DETERMINED BY FIELD EXAMINATIONS BY AGENTS OF THE BUREAU OF ENTOMOLOGY, AND IN CERTAIN CASES BY THE ENTOMOLOGISTS OF THE STATES CONCERNED. IN 1909 AND 1910 THE STATE ENTOMOLOGIST OF MISSISSIPPI FURNISHED CONSIDERABLE INFORMATION, AS DID THE ENTOMOLOGIST OF ALABAMA IN 1910 AND 1911
INDICATES THE LIMIT OF THE TERRITORY INFESTED AT THE END OF THE SEASON OF 1911.
LIMIT OF THE COTTON BELT
1911
1910
1909
1908
1907
1906
1905
1904
1903
1901
1898
1897
1895
1894
1893
1892

FIG. 21.—The spread of the cotton-boll weevil from 1892 to 1911. (From Hunter.)

The fall movement of the weevil has been studied carefully each year since 1904. (See fig. 21.) The circumstances have been different each season, but with uniformity within certain limits. Several examples will be given. In the fall dispersal of 1904 the weevils seemed to have crossed the line of continuous infestation in southern Louisiana about August 1, and a little later toward the north, but in all cases the movement had crossed the line by the 20th of August. In this year there were two very well-defined dispersals with about a month intervening. This might indicate that the first dispersal was caused by the lack of food and that in another month a new generation found itself confronted by the same conditions as its predecessor and was also forced to disperse.

In 1906 the movement seems to have been more irregular, for the first serious new infestation was in central Louisiana rather than in the southern part of the State. In the light of present knowledge this was probably due to the smaller amount of cotton grown in the pine woods of southern Louisiana, which naturally gave rise to comparatively few weevils for the flight. The year 1906 was the last in which any appreciable movement into western Texas was observed until 1910.

In 1907 and 1908 the eastward and northeastward progress of the weevil carried it far into regions where much cotton is produced. The year 1909 exhibited some very striking features. There had been a considerable loss in the infestation during the winter of 1908 in northern Louisiana and eastern Arkansas, a region of very extensive cultivation of cotton. During the autumn of 1909 the almost continuous movement in southern Mississippi from field to field in the rather sparsely cultivated areas amounted to 120 miles for the season. In the delta region of Louisiana, Mississippi, and Arkansas, where the weevils encountered a belt of extensive cotton culture from which they had been driven back during the previous winter and were stopped by the large amount of food available, they were unable to gain more than 20 miles of new territory.

In 1910 a peculiar situation developed. It was discovered that high winds had caused an extensive movement into central Mississippi in May or June. In the entire history of the weevil there had previously been known but one occasion when a severe storm caused a dispersal of the insect. A study of the records of the Weather Bureau brings out the fact that there was a series of cyclonic storms about May 7, 1910, passing northeastward across Mississippi from the heavily infested regions around Natchez. We have been unable to find any other explanation of such an extensive movement in the early spring. Studies conducted during the summer and fall of 1910 revealed the existence of many sporadic infestations throughout central Mississippi, probably due to the storm. From these isolated infestations the weevils spread in concentric circles until about the end of November, when the intervening territory became covered.

The winter of 1909–10 was unfavorable to the weevil in the Delta. When the dispersion season opened it was noticed that in strong contrast to the rapid movements in central Mississippi, the weevils in the Delta advanced slowly. During the entire season there were only two courses of considerable movement in the Delta region. One of these was along the Mississippi River through the fields adjoining the levees. The other extensive movement in the Delta country was in a belt coincident with a strip known locally as the "dogwood ridge."

The winter of 1910–11 also was unfavorable to the weevil. It began with a sudden freeze on October 29, which extended over almost the entire infested region and destroyed the food supply. Severe cold weather in January also contributed to the control. Examinations made in June and August, 1911, demonstrated that the weevil was in the lowest average condition numerically that it had ever reached. It was completely exterminated in the northern portion of the Texas and Oklahoma black prairie, but west of this was a region which escaped the first frost, and where the weevils occurred in more or less normal numbers.

The defoliation by the leaf worm was so widespread that a condition of maximum infestation was reached with much smaller numbers of weevils than usual, and the scarcity of proper food supply forced a phenomenal advance along the Mississippi River toward Tennessee.

In Texas and Oklahoma there were some gains made in the lost territory, but even with these gains 24,000 square miles of territory were not reinfested. The northern limit of cotton production in western Arkansas was reached, and the line of infestation stopped only about 10 miles short of the southwestern corner of Tennessee. Great gains were made in northern Mississippi, and western Alabama and Florida became invaded for the first time.

HIBERNATION FLIGHT.

The fall dispersion movement continues more or less regularly until frosts occur and mark the beginning of the hibernation period. Thus, in many cases the fall dispersion is a flight into winter quarters. However, a period of feeding seems to be necessary for successful hibernation. Therefore, few of the dispersing weevils which are forced into hibernation by cold weather survive. Those that do survive seem to be supplied from a distinct movement into hibernation quarters at the end of the season. The most striking observation on this point was made by Mr. J. D. Mitchell in the winter of 1906. Although there had been no lowering of the temperature, he found on entering the cotton fields on November 18 a very restless activity among the weevils. Adults were observed upon the squares with their wings open and flew at the least disturbance. He observed many hundreds of weevils rising into the air and disappearing. The weather was warm and pleasant, and there appeared no reason at the time for this flight, which continued for about two days. In a few days the temperature became decidedly lower, and Mr. Mitchell was able to find only a very few weevils remaining in the fields. This note is of special interest in connection with the observations on climatic control, which will be discussed later.

OTHER FORMS OF NATURAL SPREAD.

Heavy windstorms, hurricanes, and cyclones are powerful agents in the spread of the weevil. It is believed that the great storm of September 8, 1900, in Texas, carried the infestation northward many miles. As has been stated, the storms of about May 7, 1910, in Mississippi, were instrumental in causing a considerable increase of the infested territory in that State.

There is another method of natural spread of some local importance. In hill lands, especially, rains sweep immense numbers of infested squares to the lower parts of the fields. Cotton squares are remarkably impervious to water, and weevils may develop in them after decay is far advanced. These squares may be carried many miles from their source and deposited under favorable conditions for the emergence of the weevils.

ARTIFICIAL DISSEMINATION.

While the natural dispersion of the boll weevil is by far the most important means by which new territory becomes invaded, there are certain artificial means of dissemination which are of some importance. The more noteworthy of these are connected with the handling of the cottonseed and cottonseed products. Many weevils are carried to the gins with the cotton. From the gins dissemination may take place in several ways. The weevils may be carried back to the farms in cottonseed to be used for planting, or they may be shipped by rail to the oil mills along with the seed. Moreover, weevils are likely to secrete themselves during cool weather in the wrapping of cotton bales. In this manner transportation along with the lint is possible, although experience has shown that the danger from this source is inconsiderable. When the cottonseed arrives at the oil mill there is chance of infestation from flight into neighboring cotton fields. The greater damage, however, is in the shipment of weevils beyond the oil mills in the cars which have been used for the purpose of carrying the seed to those establishments.

Among the means of minor importance may be mentioned the incidental carriage by vehicles, including railroad coaches, by the movement of plantation laborers, and by intentional carriage for the purpose of experimentation or exhibition. The possibility of spread by these various means will be discussed in the following paragraphs:

MOVEMENT OF SEED COTTON.

Many immature or teneral weevils are carried to the gins with the seed cotton. Adults are frequently found crawling over the wagons filled with unginned cotton. The devices for removing foreign matter from cotton in the process of ginning are numerous and effective. Many of the weevils are removed or destroyed, but adults, as well as larvæ and pupæ, are likely to pass through the gin with the seed. This has been determined by the Bureau of Entomology by running gins experimentally.[1] Many of the weevils, consequently, are carried into the seedhouse along with the cottonseed. Moreover, many of those that are removed by the cleaning devices are not injured. They pass along with the motes into a barrel or box, which is generally uncovered, and from there they frequently fly about and find their way into the cottonseed, or they may secrete themselves in the bagging of the bales standing in the gin yard. Furthermore, many of the adult weevils are not taken into the gin house at all. Being on the cotton in the wagon, they are disturbed by the process of unloading and may fly to any portion of the plant. Consequently, cottonseed in storage at the gin may become infested by any one of the following means: (1) By passage of weevils through the gins along with the seed; (2) by the weevils finding their way into the seed house from the receptacle containing the discharge from the cleaner feeder; and (3) by flight from the wagons during the process of unloading. Thus, gins may serve as important agencies in the dissemination of the boll weevil by the shipment of the seed or possibly of baled cotton. That the danger in baled cotton is slight is shown by the fact that no colonies have been found to have become established in spite of extensive shipments out of the infested territory which have been made for several years.

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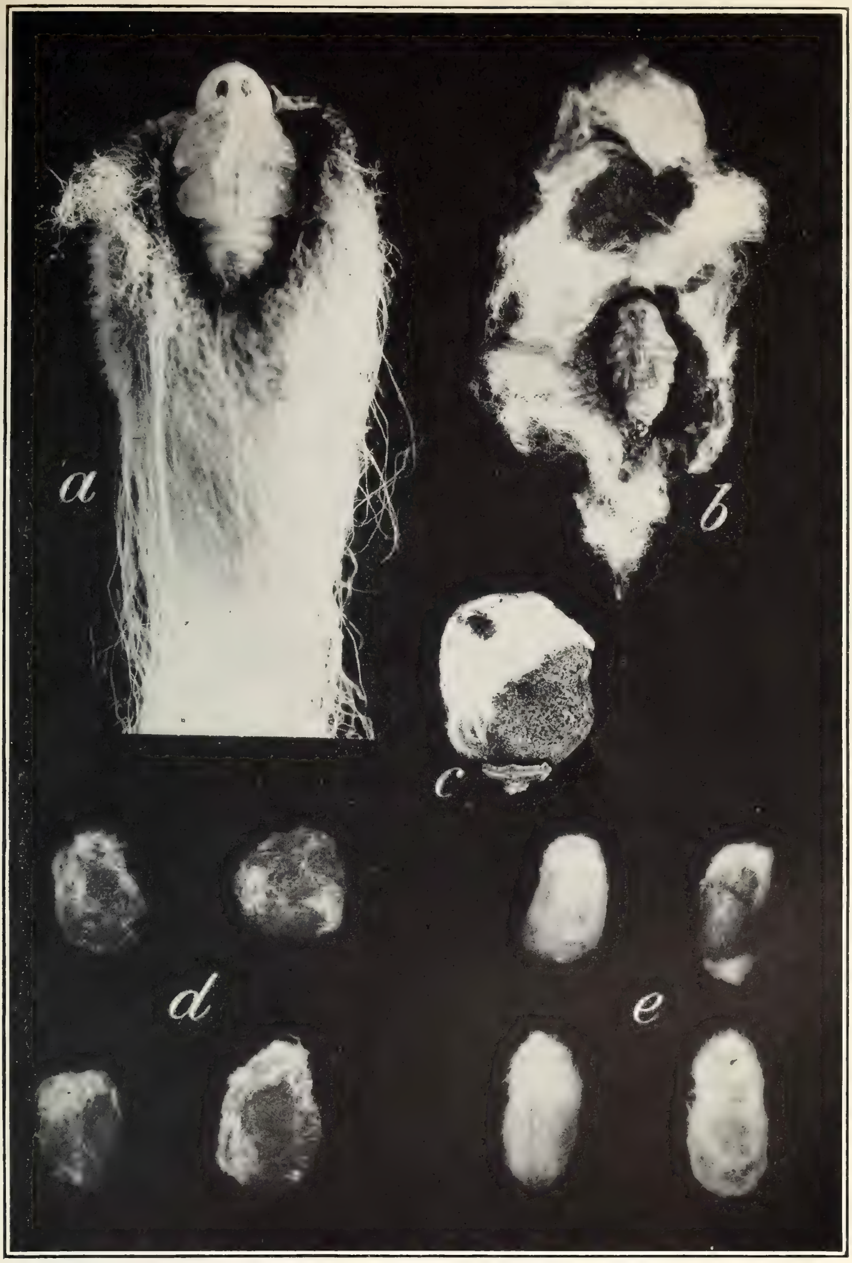
[1] For a full account of these experiments see Farmers' Bulletin 209.

In many localities the unginned cotton is carried for a distance of 20 miles or more to the gins. It frequently happens that this carriage is into uninfested territory. Under such conditions it is evident that an important form of artificial dissemination of the weevil occurs. Two examples will be given of the possibility of the dissemination of the weevil by such means. In October, 1904, a shipload of unginned cotton was carried across Lake Calcasieu, La., from Grand Lake and Lakeside to Cameron. The latter place was free of the weevil and isolated by extensive stretches of swamp lands. Shortly after the shipment reached Cameron, however, an infestation was found in the gin yard. It was in all probability due to the carriage of the cotton from the opposite side of the lake. In the other case a shipment of unginned cotton was made from Yucatan, Mexico, to Mobile, Ala., in 1909. The Mexican locality was infested by the boll weevil, while the region about Mobile was free of the insect. No infestation resulted in this case for the reason that the shipment from Mexico was accidentally delayed in transit and did not reach Mobile until all of the weevils had died. If the shipment had been made according to the regular schedule there is little doubt that an infestation in the vicinity of Mobile would have resulted.

MOVEMENT OF COTTONSEED.

In ginning districts on the edge of the infested territory the customers are composed of those whose fields are infested and those whose fields are not infested. The inevitable result is that weevils are constantly brought into the gin yards by the farmers, and in the subsequent movements of the cotton are spread broadcast. Some of them may alight upon the wagons filled with the seed to be returned to the farm and consequently may be frequently carried to uninfested farms. The most striking illustration of infestation by this means was found in Shelby County, Tex., in 1904. An establishment on the border line ginned for farmers in a radius of 10 miles or more. Some of the customers had the weevil. The ginner himself had a few weevils on his place, but had raised an exceptionally large crop of big-boll cotton, for the seed of which quite a demand arose. An investigation of the farms in this district showed that all the customers who had purchased this seed had infestations near their seed house. Very few of the other farms in the vicinity were found to be infested.

Cottonseed is frequently shipped considerable distances from the gins to the oil mills. As has been shown there are abundant chances that the seed may become infested at a gin within the infested territory. (See Plate IX.) At the oil mills the cars are unloaded and



RELATION OF BOLL-WEEVIL CELLS TO SEED.

a, Boll-weevil pupa found in cotton seed; *b*, boll-weevil pupa in cell of lint from boll; *c*, weevil cell in dwarfed cotton boll containing live pupa taken among seed; *d*, weevil cells in bolls; *e*, cotton seeds. (Original.)

passed on to the railroads for other uses, frequently without being swept out at the mills. It is common in the lumber country for cars to pass from oil mills to lumber mills. Such cars are often found containing several pounds of seed in the corners. The lumber men sweep out this waste before loading their cars. In case cotton grows near the mill the danger is quite apparent.

An interesting example of the shipment of the weevil in cottonseed came to notice in Mexico a few years ago.[1] On January 5, 1903, it was discovered that Texas-grown cottonseed was being imported into the southeastern part of the Laguna district in Mexico.[2] Examination of this seed, made by Prof. L. de la Barreda, revealed the fact that six lots had been received from infested points in Texas and that each of these lots was at that time infested with live boll weevils. The results of an examination of samples from three consignments are given in Table XXXII.

TABLE XXXII.—*Result of examination of infested cottonseed shipped to Mexico.*

Number of sacks of seed examined.	Boll weevils found.	Alive.	Dead.
8	27	2	25
4	11	2	9
2	57	10	47
14	95	14	81

The results of these careful examinations show very clearly the possibility of transporting live weevils in shipments of cottonseed. Unless the oil mill is within the infested territory and ships hulls to points outside there can be very little danger from this product. In fact, it is hardly possible that weevils are ever spread by means of cottonseed hulls.

BALED COTTON.

One of the writers has found live weevils in bagging about bales consigned to Liverpool on the wharves at New Orleans. However, as has been pointed out, experience has shown that the danger from this source is very slight.

PASSING VEHICLES.

Carriages, wagons, and railroad trains, in passing fields where the weevils are numerous, may carry them great distances, although few specific observations have been made on this matter.

MOVEMENT OF FARM HANDS.

Many laborers frequently pass from infested territory to uninfested territory. Their practice is to use cottonseed for packing breakable household articles. If the movement takes place late in the season this cottonseed or sacks used in infested fields may easily be the means of spreading the insect. It is thought probable that a sporadic infestation at Jackson, Miss., in 1908, originated by such means from the heavily infested district around Fayette, Miss.

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[1] The remainder of this and the next paragraph are from Bull. 51, p. 125.

[2] Boletin de la Comision de la Parasitologia Agricola, vol. 2, pt. 2, pp. 45–58.

UNEXPLAINED SPORADIC OCCURRENCES.

Infestations at Wichita Falls and Paris, Tex., in 1904, far removed from other infestations, can not be explained. A reported infestation in 1909 at Temple, Okla., is also of the same nature.

INTENTIONAL TRANSPORTATION OF THE WEEVIL.

On several occasions it has been found that the boll weevil has been carried into uninfested territory purposely. In some cases the intention has been merely to exhibit live specimens and in others to test supposed remedies. Whatever the purpose of these introductions may be, the practice must be strongly condemned. It is very likely to result in the infestation of localities many years in advance of the time the weevil would reach them by natural means. The result would be a great and unnecessary loss, not only to cotton planters, but to merchants and others dependent upon the cotton trade. In this connection attention is directed to the fact that a Federal statute prohibits the interstate shipment of the boll weevil, as well as other important insect pests, and prescribes heavy penalties.[1] This act is reprinted in part, under the heading "Legal Restrictions," on a subsequent page.

In addition to the Federal legislation on this subject practically all of the States in the cotton belt have statutes which prohibit the importation or having in possession of live boll weevils for any purpose whatever. (See the section at the end of this bulletin.)

HIBERNATION.[2]

There are many popular misconceptions regarding the manner in which the boll weevil passes the winter. For this reason we take the opportunity to point out some general considerations about hibernation.

Many forms of animal life suspend activity during the winter. This is the case with the boll weevil and many other insects, as well as with certain other animals. During this period of inactivity the animals which hibernate derive sufficient nourishment from a supply stored within the body to maintain life. They obtain no other form of food. In fact, the hibernation period coincides more or less with the periods in which the native food supply is absent. The temperatures which kill the cotton plant force the boll weevil into winter quarters, where it remains with suspended animation until spring. Almost coincident with the first sprouting of cotton we find the weevils leaving their winter quarters and moving about in the fields.

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[1] An act to prohibit importation or interstate transportation of insect pests, etc. (Act of Mar. 3, 1905, ch. 1501, 33 Stat. L., 1269.)

[2] Two excellent publications on the hibernation of the boll weevil have been issued. These are: "The Hibernation of the Boll Weevil in Central Louisiana," by Wilmon Newell and M. S. Dougherty (Cir. 31, La. Crop Pest Commission), and "Hibernation of the Mexican Cotton-Boll Weevil," by W. E. Hinds and W. W. Yothers (Bul. 77, Bur. Ent., U. S. Dept. Agr.).

The long absence of the weevils from the cotton fields has led superficial observers to believe that the weevils pass the egg stage in the cotton seed. Such persons point out the fact that the weevils are found in seed houses and appear most abundantly in the fields near these buildings, and also that they have found insect larvæ in the seed. As a matter of fact, the insects found in the cotton seed are not boll weevils, but other species which feed upon dried seeds and similar vegetable matter. The appearance of the early weevils in the vicinity of seed houses is due entirely to the fact that the protection offered there attracts many in the fall. Careful observations throughout the winter have shown that the boll weevil remains inactive except for very slight movements during very warm periods and that it does not breed in or feed upon cotton seed.

As explained in another portion of the bulletin, the hibernation period is defined by the continuance of mean temperatures within what we define as the zone of hibernation. This zone has as its upper limit the mean temperature above which, if continued for any considerable period, the life activities must be resumed, and has for its lower limit the absolute temperature below which no weevil can live for even a short time. For all practical purposes the hibernation zone lies between 56° and 12° F.

METHODS OF STUDY OF HIBERNATION.

In studying several features of the hibernation of the boll weevil the practice has been to utilize large cages covered with wire screen which were placed in the cotton fields. (See Pl. X, *b*.) No cotton was grown in these cages, but at different dates in the fall large numbers of weevils collected in the adjoining cotton were placed in the cages. It has been considered that the rate of survival of weevils in these cages installed chronologically is an index to the number of weevils that actually survive under natural conditions. It has thus been considered that with 1,000 weevils in a cage installed October 1, which showed a survival of 10 per cent, and a cage containing 1,000 weevils installed on September 15, which showed a survival of 5 per cent, twice as many weevils would have survived the destruction of the plants on October 1 as on September 15. Although there is no doubt that this method gives a fairly accurate index, there is one objection that can be made to it. This objection is that the number of weevils leaving the field to go into hibernation as the season progresses, the number dying in the fields, and the number maturing there are not taken into consideration as the calculations have been made. On September 15 none of the weevils in the field would have entered into hibernation. By the 1st of October, however, a certain number would have left the field, and such weevils would not be represented in the collections made for the cage installed on October 1. It is not known whether the weevils which remain in the fields late are more or less hardy than those which leave early to find hibernating quarters. The indications, however, are that the stronger and more active weevils—that is, those more likely to survive the winter—are the ones which do not go into hibernation at an early date. Nevertheless the number that may have gone into hibernation between the dates of the installation of the various cages, the number that died from natural causes, and the number that matured in the fields during that time must be considered. As a matter of fact, the total number of weevils in a locality on October 1 would be the number present in the cotton fields on September 15, less the total number dying between September 15 and October 1, and less the number leaving the field to enter into hibernation during that period, plus those that matured during the same time. It is likely that the number of weevils maturing is generally sufficient to offset the number that die from natural causes. This leaves only the weevils which escape collection by entering into hibernation to be considered. As there is no way in which this number can be determined, the method we have followed, which ignores them altogether, is the closest approximation we can make to a determination of the actual number of weevils which succeed in passing the winter after the destruction of the food plants in the fall.

It is to be noted that the possible error in the interpretation of the results of hibernation experiments becomes greater in the case of the cages installed late in the season. As the season advances more and more of the weevils leave the fields and thus pass out of consideration in connection with the number collected and placed in the cages.

The hibernation experiments conducted have dealt with 181,932 weevils utilized in seven different seasons in seven localities throughout the infested territory.

ENTRANCE INTO HIBERNATION.

SOURCES OF WEEVILS ENTERING HIBERNATION.[1]

Following the maturity of a considerable portion of the crop of bolls, and usually in connection with the occurrence of a heavy rainfall, a renewed growth of the plant commonly produces an abundance of squares. It is this late top growth of the plant, which serves no good purpose so far as further production of cotton is concerned, that is primarily responsible in most fields for the needlessly large number of weevils produced between the time of maturity of the crop and the usual time of destruction of the plants by frost. A large proportion of the weevils which become adults before September 1 may be expected to die, either as cold weather comes on or during the early part of the winter season. There is no particular hibernation brood, but representatives of all generations may survive and enter hibernation, as has been shown by figure 14 in the discussion of the life cycle.

STAGES ENTERING HIBERNATION.[2]

The reproductive activity of the weevil continues steadily until the plants are destroyed by frost, but it gradually decreases coincidently with the gradual decrease in temperature. All stages from the egg to the adult may be found in both squares and bolls, even after frosts have occurred. The immature stages in squares are not immediately killed unless the freeze is exceptionally severe, and in some localities many of these survive to reach maturity and to emerge during the following spring. Usually, however, only those which are nearly adult at the time frost occurs may be expected to

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[1] The matter in this section is mainly extracted from Bull. 77, Bureau of Entomology, pp. 12, 13.
[2] The matter in this section is largely extracted from Bull. 77, pp. 13, 14.

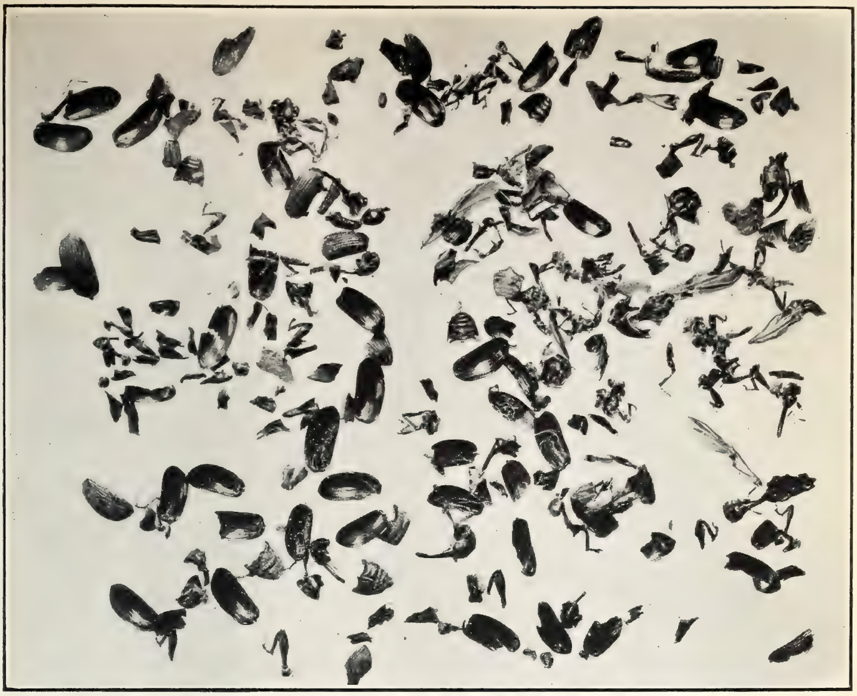

FIG. *a*.—BOLL-WEEVIL REMAINS AFTER PASSING THROUGH FAN FROM GIN. (ORIGINAL.)

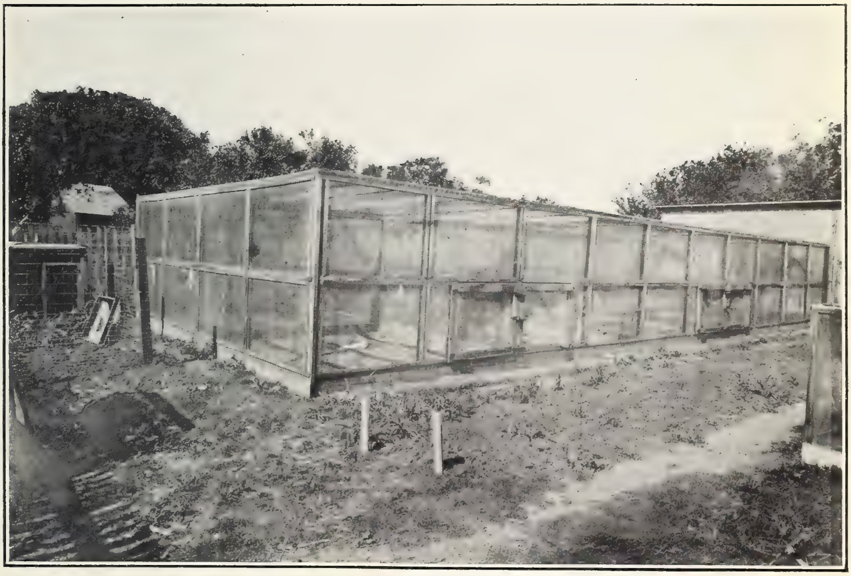

FIG. *b*.—TEN-SECTION HIBERNATION CAGE. (ORIGINAL.)

Fig. a.—Cotton field adjacent to timber covered with Spanish moss. (Original.)

Fig. b.—Proximity of moss-laden trees, conducing to high infestation by weevil. (Original.)

HIBERNATION CONDITIONS FOR THE BOLL WEEVIL.

emerge. These might emerge upon warm days following the colder weather, but in the absence of a fresh food supply would soon die. In the fall of 1903 Prof. E. D. Sanderson, in an examination of 700 squares at the middle of November, found 79 eggs, which means that 11 per cent of the squares contained eggs. In an examination of 1,600 squares he states that 366 larvæ were found, showing that about 23 per cent of the squares contained larvæ at the time of entrance into hibernation.[1] Some stages may survive in squares for a short time after the freeze, but there are few records of weevils entering hibernation as immature stages in squares and surviving to emerge therefrom in the spring. These stages are therefore unimportant from an economic point of view.

With immature stages entering hibernation in bolls, the case is quite different from that in squares. Very large numbers of weevils enter upon the period of hibernation as immature stages and during many seasons, especially in the southern part of the State, a large percentage of these complete their development, and many survive until time for their emergence in the spring. Immature stages in bolls have been found alive at Victoria, Tex., as late as February 17.

TIME OF ENTERING HIBERNATION.

Hibernation begins when the temperature reaches a point between 60° and 56° F. The exact point will be higher with a high percentage of humidity and lower with a low percentage of humidity.

According to the observations of Messrs. Newell and Dougherty.[2] at Mansura, La., in 1908, entrance into hibernation began on October 28. The mean temperature for 10 days preceding that date was 63.7° F., but the minimum dropped from 46° to 31° F. on the day the weevils began to enter into hibernation.

The action of the weevils in securing shelter from approaching cold is instinctive rather than intelligent. It is probably true that they have no such sense of sight as we commonly understand from the use of that word and that their selection of shelter is not at all guided by that sense. We mean by this that a weevil on a cotton plant can not see at any distance shelter which might be attractive to it and thereupon fly from the plant to the shelter. Cold nights with a temperature between 40° and 50° F., succeeded by warm still days, such as occur commonly in the fall, seem to stimulate the weevils to an unusual activity both in flight and in crawling. It seems possible that they have an instinctive knowledge of the approach of temperature conditions from which they must secure shelter, but it is also true that many weevils remain active upon plants for some time after the plants have been destroyed by frost and frequently until several weeks after other individuals have entered hibernation. In speaking of entering hibernation, therefore, we mean the entrance of the weevils upon a period of comparative if not complete inactivity. Their action in securing shelter is gradual and governed primarily by the degree of protection from the cold which they may receive. If early in the season a weevil accidentally finds shelter which gives it exceptional protection from the cold it will likewise be exceptionally protected from heat and therefore less likely than are other less fortunate individuals to resume its activity upon warm days. If at first the shelter which weevils find is only slight they will be easily influenced by succeeding warmth, and in another period of activity will be likely to find better protection. Their flight upon warm days undoubtedly leaves large numbers of them outside of the cotton fields, where they are more likely to find favorable shelter than within the fields themselves.

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[1] Bull. 63, Bureau of Entomology, U. S. Dept. of Agriculture.
[2] Cir. 31, Lousiana Crop Pest Commission, p. 170.

From this explanation it will be understood that it is rarely possible to indicate by a single date the time when weevils enter hibernation. It may be better expressed as a period within the limits of which a large majority, though possibly not all, weevils may seek shelter. Naturally this time varies according to the seasonal temperature conditions, so that in a certain locality it may occur several weeks earlier in one season than in another. It is also evident that differences in temperature conditions due to latitude or altitude will cause a similar variation in the time when weevils enter hibernation.[1]

In Table XXXIII are shown the times of the year in which the weevils entered hibernation in the experiments of 1903 to 1906, together with the temperature conditions prevailing. The table shows the relationships between humidity and temperature and the length of the period of entrance into hibernation. In short, it may be stated that the lower the mean temperature the shorter the period of entrance. Sufficient information is not at hand to show positively the influence of humidity, but it is evident that there is a decided influence.

TABLE XXXIII.—*Period of entrance of the boll weevil into hibernation and meteorological conditions.*

Year.	Locality.	Period.		Mean temperature.	Mean humidity.
		Limits.	Days.		
				°F.	*Per cent.*
1905	Dallas, Tex	Nov. 29–Dec. 8	10	40.5	64.8
1903	College Station, Tex	Nov. 15–27	13	49.5	
1903	Victoria, Tex	Nov. 15–30	16	53.0	
1905	do	Nov. 30–Dec. 18	19	50.0	
1904	Corsicana, Tex	Nov. 10–Dec. 5	26	55.0	
1906	Dallas, Tex	Nov. 12–Dec. 8	27	53.0	73.1
1904	Victoria, Tex	Nov. 11–Dec. 8	28	57.5	79.3
1906	do	Nov. 9–Dec. 21	43	60.4	

Weevils can not be forced to hibernate when conditions do not normally induce hibernation. If kept without food, they will starve. The real bearing of this statement will be brought out later in connection with the summaries of the survival in its relation to the time of beginning hibernation. (See Table XLVI.)

NUMBER OF ADULT WEEVILS ENTERING HIBERNATION.

Of course the number of adult weevils entering hibernation is a variable quantity, owing to the differences in the percentage of infestation in various regions and seasons. Examinations in heavily infested regions have shown averages as high as 58,000 adult weevils per acre in the middle of November. In this connection it is interesting to note the progress of entrance into hibernation as shown by Table XXXIV, based on investigations made at Dallas in fields with an average of 8,300 plants per acre.

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[1] This and the preceding paragraph are remodeled from Bull. No. 77, Bureau of Entomology.

TABLE XXXIV.—*Number of boll weevils per acre upon stalks at different dates at Dallas, Tex.*[1]

Date.	Plants examined.	Living weevils found.	Living weevils per acre.
1906.			
Oct. 12	110	122	9,205
Oct. 31 to Nov. 3	84	190	18,774
Nov. 10	60	106	14,663
Nov. 20	35	29	6,877
Nov. 22	35	27	6,403
Dec. 1	36	10	2,306
Dec. 18	35	5	1,186
1907.			
Jan. 21	35	3	711

[1] From Bull. 77, Bureau of Entomology, p. 18.

In connection with this subject we include also Table XXXV for the same period, showing the occurrence of the weevils under shelter on the ground in the cotton fields.

TABLE XXXV.—*Number of weevils under rubbish on ground at Dallas, Tex.*[2]

Field.	Date examined.	Portion of acre examined.	Weevils found—		Total per acre.	Percentage alive.	Remarks.
			Alive.	Dead.			
	1906.						
A	Nov. 15	22 plants.	4	0	1,450	100.0	In cracks of ground around bases of plants.
A	...do....	1/264	4	0	1,056	100.0	Under rubbish on ground.
A	Nov. 22	1/347	8	0	2,776	100.0	Do.
A	Dec. 18	1/264	5	14	5,016	26.3	Do.
	1907.						
B	Jan. 11	10/8384	5	2	5,870	71.4	Northeast corner of field.
C	Jan. 29	10/6236	1	1	1,247	50.0	Middle of field.
C	...do....	10/8384	2	2	3,354	50.0	Near southwestern edge.

[2] This table and the following paragraph are taken from Bull. 77, Bureau of Entomology, p. 20.

The sum total of weevils found both on plants and on the ground on November 22 shows an average of slightly more than 9,000 weevils per acre, all of which were alive. On December 18 the number that could be accounted for was between 6,000 and 7,000 per acre on the same ground which had been previously examined. On the former date more than two-thirds of the weevils were still upon the plants. On the latter date nearly five-sixths of them were on the ground, and among those on the ground only 26 per cent were living. These figures show that between November 22 and December 18 a very large mortality had occurred among weevils which had entered hibernation, and especially among those which had sought shelter under rubbish upon the surface of the black-waxy soil of field A.

SHELTER DURING HIBERNATION.

Boll weevils in seeking shelter from the cold will enter all kinds of places which might afford shelter. The following statements are quoted from Prof. E. D. Sanderson:[1]

> The observations by Prof. Conradi at College Station, Tex., in the early winter of 1903, probably indicate some of the normal places for hibernation—that is, under dead leaves, in old cotton brush, and under loose bark. In the hibernation cages, where the weevils were furnished an abundance of rubbish, it was found that many of them which were hibernating successfully had crawled into the cavities made by borers in dead wood and in similar positions where they were well protected. It has been often noticed that in a wooded country the weevils appear first in spring along the borders of fields next to the woods and gradually work inward from the edges, so that it seems probable that in a wooded country most of them hibernate in woodland. Around outbuildings and barns also are found favorable places, as there is always more or less rubbish and protection in such situations. In 1903 more than five times as many weevils were found in a piece of cotton near the college barn, where cotton had been grown the previous year, than were found in any other locality in that neighborhood. It is also noticeable that weevils are always more numerous near gins than at a distance from them.
>
> It is noticeable that weevils are much more abundant where cotton is planted in fields where sorghum stubble has been allowed to remain all winter adjoining a last year's cotton field.
>
> Professor Mally has given the observations of Mr. Teltschick upon finding weevils hibernating in the crevices of the soil around the cotton stalks and roots, at a depth of 3 inches. On March 7, 1901, a raw, windy day, upon 35 stalks, he found 7 live and 2 dead weevils from 1 to 3 inches below the surface. In September, 1902, he stated that he had again found weevils in a similar situation during the previous spring, but not as many of them as in 1901. Mr. Teltschick recently writes as follows:
>
> "I found but few weevils in crevices around stalks during the last two winters, partly because there were no crevices (frequent rains filling them up as soon as formed) and partly because freezes were severe enough to keep cotton from coming out during any part of the last two winters; whereas in 1900 we had neither rain enough to fill up crevices nor frost enough to keep cotton from budding out at intervals at the base of the stalk, which latter fact accounts, no doubt, for the relatively large number of weevils found within the crevices."

Where the cotton stalks are allowed to stand throughout the winter they furnish the weevils both the means of subsistence late in the fall and an abundance of favorable hibernation places throughout the field. The prospects of successful hibernation are thereby multiplied many times, and, furthermore, the weevils are already distributed over the field when they first become active in the spring. The grass and weeds which almost invariably abound along fence lines are exceedingly favorable to the hibernation of many weevils, so that it will be found generally true that the worst line of infestation in the spring proceeds from the outer edges of the field inward. Where cotton and corn are grown in adjacent fields, or where, as is sometimes the case, the two are more or less mixed in the same field, many weevils find favorable shelter in the husks and stalks of the corn. An especially favored place is said by Mr. E. A. Schwarz to be in the longitudinal groove in the stalk and within the shelter of the clasping base of the leaf. Perhaps the most favorable of all hibernating conditions are to be found among the leaves and rubbish abounding in the edges of timber adjoining cotton fields and in Spanish moss. From such sources the weevils are known to come in large numbers in the spring. Sorghum stubble, which collects débris blown about by the wind, is also very favorable for hibernation.

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[1] Bull. 63, Bureau of Entomology, U. S. Dept. Agriculture, pp. 18–19.

Fig. a.—Standing dead timber and forest environment favorable for hibernation of weevils. (Original.)

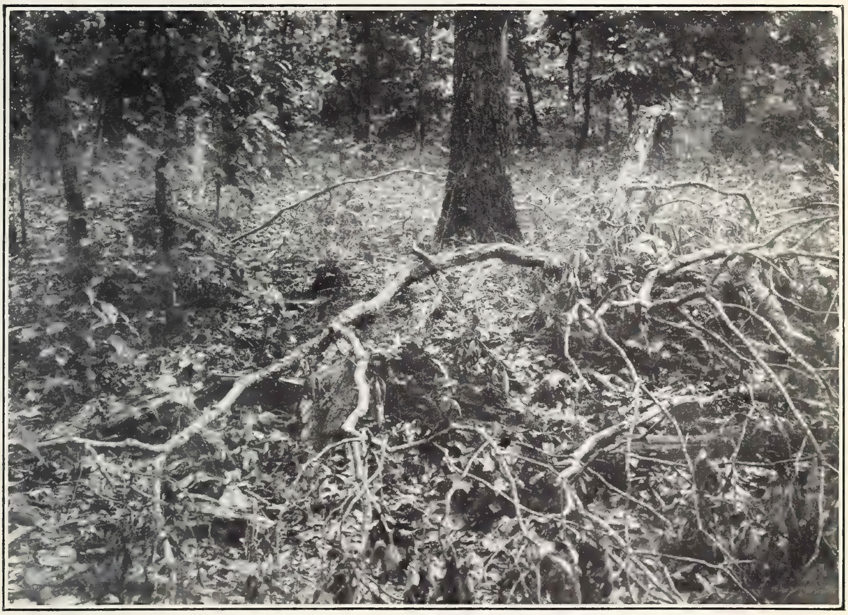

Fig. b.—Litter in forest, suitable for hibernation of weevils. (Original.)

HIBERNATION CONDITIONS FOR THE BOLL WEEVIL.

Fig. a.—Spanish moss on trees; very favorable for hibernation of weevils. (Original.)

Fig. b.—Density of Spanish moss as a protection to weevils in hibernation. (Original.)

HIBERNATION CONDITIONS FOR THE BOLL WEEVIL.

Attention has already been called to the fact that many stages enter the period of hibernation in an immature condition in unopened bolls. That adult weevils hibernate entirely within the protection afforded by the bracts and hulls of bolls has been abundantly demonstrated. Messrs. Hinds and Yothers[1] showed, however, that the percentage of live stages in bolls decreased rapidly during the winter, thus proving that the bolls do not furnish perfect hibernation shelter. Their results may be summarized as follows:

TABLE XXXVI.—*Seasonal decrease of live stages of the boll weevil in bolls; percentage of bolls containing live stages.*

December	36.00
January	1.15
February	0.29
March	0.00

As would be expected, it was found that there was a greater percentage of survival in bolls in southern localities.

During an ordinary season it can not be doubted that a large majority of the weevils which survive find some other shelter than the bolls hanging upon the plants. It is not, however, as easy a matter to find weevils in rubbish scattered upon the ground as in bolls. It is necessary to collect the rubbish very carefully and sift it over cloth or paper to separate the weevils from the trash. In this way it has been found that weevils hibernate extensively in the leaf and grass rubbish distributed throughout the field. Naturally, the cleaner the field in the fall the smaller will be their chances of finding favorable shelter during the winter.[2] (Pl. XII, *b*.)

Standing trees are a common sight in cotton fields, and while the records of weevils found hibernating under bark are but few, they are sufficient to indicate that these trees may be rather important factors where they occur in considerable numbers. (Pl. XII, *a*.)

Where the Spanish moss (*Tillandsia usneoides*) occurs, as in the bottom lands in the coast section of Texas and in the southern portions of the Gulf States generally, weevils find exceptionally favorable shelter. Many examinations of large quantities of moss have been made to ascertain the importance of this form of shelter. The maximum number of weevils per ton of moss is recorded by Messrs. Newell and Dougherty (1909) as 3,158 in moss collected from an elm tree located in a swamp at Mansura, La., December 23, 1908. The moss was at a height of 15 feet. The tree was one-fourth of a mile from the nearest cotton field. On January 9, 1910, Mr. C. E. Hood found at Mansura 924 boll weevils and 2,156 boll-weevil parasites per ton of moss collected at from 1 to 8 feet above the ground. The weevils seem to prefer the festoons of green-hanging moss to the dead masses. (See Pls. XI, XIII.)

Cornfields adjoining cotton, or cornstalks scattered throughout cotton fields may shelter many weevils. This was first noticed by Mr. E. A. Schwarz at Victoria, Tex., in the winter of 1901–2, and has since been corroborated by a number of observers. Several examinations have been made of haystacks in the vicinity of cotton.

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[1] Bull. 77, Bureau of Entomology.

[2] This paragraph and the remainder of the discussion in the present section is modified from Bull. 77, Bureau of Entomology, pp. 30–33, 41, 42.

This is a task quite comparable with that of seeking for the proverbial needle, and it is not surprising that the results have been very meager. The fact, however, that traces of weevils have been found in these examinations indicates that weevils may find shelter under such conditions.

Farmyards, seed houses, barns, ginneries, and oil mills also afford favorable shelter for weevils. Especially in ginneries and seed houses the weevils become concentrated with the cotton or seed and frequently may be found in large numbers within or around these buildings. In connection with this subject the reader is referred to a fuller discussion of the significance of ginneries and oil mills in the distribution of weevils and of the methods recommended for controlling them.[1]

In order to have a basis of comparison of the various kinds of shelter, many cage experiments have been conducted. In Table XXXVII will be found a comparison of the survival in the cages at Keatchie, La., for weevils installed November 23 and 29.

TABLE XXXVII.—*Favorable conditions for hibernation determined by rank in percentage of weevils surviving at Keatchie, La., in 1905–6.*[1]

Nature of shelter.	Weevils put in.	Weevils survived.	
		Number.	Per cent.
Ordinary field stalks, grass, etc	2,000	93	4.65
Brush, leaves, stumps, logs; stalks standing	2,500	99	3.56
Same as above, but stalks removed	3,300	70	2.12
Cotton seed, piled but uncovered; stalks standing	2,000	30	1.50
Absolutely bare ground	2,000	30	1.50
Cotton seed piled and covered; stalks left standing	2,000	23	1.15

[1] From Bull. 77, Bureau of Entomology, p. 42.

It is evident from these observations that ordinary field conditions where stalks are allowed to stand together with the grass and leaves littered over the ground are as favorable as any other for successful hibernation. One fact should be emphasized in regard to classes of shelter which have been mentioned as occurring within cotton fields, i. e., that it is possible, as a rule, to destroy or remove practically all of them. Undoubtedly the burning of cotton stalks, weeds, grass, and other rubbish is the easiest and most effective method of destruction where it can be practiced. Next to this in importance would be the destruction of the stalks by a stalk chopper and plowing under all the rubbish. In the latter case it must be stated that many weevils which, under dry conditions, are buried not more than 2 inches will be able to escape through the soil and may then find shelter near, if not within, the field.

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[1] Farmers' Bull. 209, U. S. Dept. of Agriculture, "Controlling the Cotton Boll Weevil in Cotton Seed and at Ginneries."

ACTIVITY DURING THE HIBERNATION PERIOD.

It is natural to expect that during warm periods of winter the temperature will rise to a point which forces the weevils into activity. Of course, the weevils under the lightest shelter are the ones which first become active. It is these warm periods which cause the intermittent development of the immature stages in dry bolls left in the fields. In some winters the hibernation is incomplete throughout the cotton belt, and in the extreme South it is probably so almost every winter. This same temperature condition is responsible for the growth of sprout cotton, which affords food in the warm periods. Observations were made in January, 1907, on weevils feeding on sprout cotton at Victoria, Tex., at a mean temperature of 67° F.

DURATION OF HIBERNATION PERIOD.

AVERAGE LENGTH OF HIBERNATION PERIOD.

Many factors must be considered in arriving at the average length of the hibernation period. The time of entrance, condition of the weevils on entering, temperature and humidity before and during hibernation, and nature of shelter, all have a decided effect upon the duration of hibernation. In a series of condensed summaries we have attempted to show how some of these factors act.

In Table XXXVIII is to be found a general summary of the nine large experiments conducted, with the extreme variations in each series. From this table it appears that in the years 1906 to 1911 the hibernation period has ranged between 62 and 255 days, and that in 1909 the range fell short only 1 day of this maximum range. It also appears that the average duration in Texas is 26 days shorter than in Louisiana. The period of emergence extends from February 15 to July 1.

Table XXXVIII.—*Extremes of variation in duration of hibernation by the boll weevil.*

Place.	Total number weevils emerged.	Total number weevil days.	Minimum period.	Maximum period.	Minimum average.	Maximum average.	Average of averages.	Earliest emergence.	Latest emergence.
			Days.	*Days.*	*Days.*	*Days.*	*Days.*		
Keatchie, La., 1906....	731	114,192	108	222	136	178	156	March 22....	June 28.
Mansura, La., 1909.....	3,260	516,067	62	254	94	199	156	February 21.	June 29.
Mansura, La., 1910.....	1,038	170,212	86	232	114	217	164	February 15.	June 15.
Tallulah, La., 1910.....	317	58,245	103	237	126	224	183	February 15.	June 27.
Tallulah, La., 1911.....	46	6,587	107	231	118	158	143	February 15.	June 4.
Louisiana average............	5,392	865,303	62	254	94	224	160	February 15.	June 29.
Victoria, Tex., 1907....	3,028	383,797	92	223	95	146	126	February 28.	June 15.
Calvert, Tex., 1907.....	1,842	255,831	91	255	100	195	138	March 4.....	July 1.
Dallas, Tex., 1907......	3,462	481,271	85	233	98	168	138	March 1.....	June 19.
Dallas, Tex., 1908......	118	17,839	113	217	121	170	151	March 2.....	June 16.
Texas average...	8,450	1,138,738	91	255	98	195	134	February 28.	July 1.
Grand total.....	13,842	2,004,041	62	255	94	224	144	February 15.	July 1.

TABLE XXXIX.—*Average length of hibernation period of the boll weevil as related to date of installation.*

Place.	Time of installation, Sept. 16–30.		Time of installation, Oct. 1–15.		Time of installation, Oct. 16–31.		Time of installation, Nov. 1–15.		Time of installation, Nov. 16–30.		Time of installation, Dec. 1–15.		Time of installation, Dec. 16–31.		Average hibernation.
	Length of hibernation.	Emerged.	Length of hibernation.	Emerged.	Length of hibernation.	Emerged.	Length of hibernation.	Emerged.	Length of hibernation.	Emerged.	Length of hibernation.	Emerged.	Length of hibernation.	Emerged.	
	Days.		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*		*Days.*
Keatchie, La., 1906	....	....	....	....	....	....	....	....	158	May 1	146	Mar. 1	....	....	....
Mansura, La., 1909	183	Mar. 31	170	Mar. 27	185	Apr. 30	157	Apr. 11	143	Apr. 15	124	Apr. 13	94	Mar. 26	....
Mansura, La., 1910	217	May 3	180	Apr. 8	165	Apr. 7	162	Apr. 22	159	Apr. 26	146	May 5	....	....	....
Tallulah, La., 1910	224	May 5	219	May 17	173	Apr. 15	162	Apr. 16	145	Apr. 20	....	(1)	....	....	....
Tallulah, La., 1911	....	....	156	Mar. 20	125	Mar. 5	....	(1)	....	(1)	....	(1)	....	....	....
Louisiana weighted average	185	Apr. 3	190	Apr. 16	183	Apr. 24	158	Apr. 15	151	Apr. 23	129	Apr. 16	94	Mar. 26	160
Victoria, Tex., 1907	....	....	....	....	139	Mar. 14	132	Mar. 22	113	Mar. 19	....	....	....	....	....
Calvert, Tex., 1907	....	....	166	Mar. 28	175	Apr. 18	142	Apr. 1	119	Mar. 24	100	Mar. 13	....	....	....
Dallas, Tex., 1907	....	....	168	Mar. 29	149	Mar. 20	135	Mar. 26	125	Mar. 29	98	Mar. 14	....	....	....
Dallas, Tex., 1908	170	Mar. 17	160	Mar. 21	157	Apr. 1	141	Mar. 30	122	Mar. 20	....	....	....	....	....
Texas weighted average	170	Mar. 17	166	Mar. 21	151	Mar. 23	135	Mar. 23	116	Mar. 9	98	Mar. 14	....	....	134
Grand weighted average	176	Mar. 18	180	Apr. 4	168	Apr. 9	139	Mar. 27	130	Apr. 2	126	Apr. 13	94	Mar. 26	144

[1] No emergence.

Knowing that the time of entrance affects the percentage of survival, it is also reasonable to expect an effect upon the duration of the hibernation period. Table XXXIX has been constructed to show the average duration and average date of emergence at each locality for all weevils entering hibernation in each half month during the several seasons of the experiments. It will be noted that the length of the period, with a few minor exceptions, decreases in accordance with the lateness of entrance. It is very strikingly shown that in any given period of entrance the duration in Texas is considerably shorter than in Louisiana. On the other hand, it is impossible to show from this table any progression in the average date of emergence.

The diagram (fig. 22) shows graphically the correspondence between date of installation and period of hibernation and emphasizes the differences between Texas and Louisiana.

RELATION OF SHELTER TO DURATION OF HIBERNATION.

That the nature of the hibernating quarters has a direct bearing upon the duration of the period is to be gathered from the records of Messrs. Newell and Dougherty made at Mansura, La., in 1909, which are abstracted below:

TABLE XL.—*Comparison of length of hibernation of the boll weevil in different shelters at Mansura, La., 1909.*[1]

Date started 1908.	Nature of hibernation quarters.	Location of cage.	Number of weevils contained.	Number of weevils surviving winter.	Average number of days in hibernation.	Average date of emergence.
October 26	Average	In open field	1,294	325	169.1	April 13
Do	do	In swamp	1,142	162	173.3	April 17
Do	Moss	In open field	1,214	409	190.9	May 4
Do	do	In swamp	938	408	199.4	May 13
Total			4,588	1,304		
Average					185.0	April 28

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[1] This table and the following statements are extracted from Cir. 31, State Crop Pest Commission of Louisiana.

Consideration of Table XL reveals the interesting fact that weevils hibernating in the cool, shaded situations in timber remained in hibernation an average of about seven days longer than those hibernating in the open field. Weevils which hibernated in moss in the swamp remained in hibernation practically 200 days, and those which passed the winter in moss on trees in the open field remained in hibernation 191 days. In marked contrast to this the weevils that hibernated in a general assortment of materials in the open field remained in hibernation only 169 days, though gathered from the cotton fields at exactly the same date in the fall of 1908. This proves the dangerous nature of the moss, for it really causes the weevils in it to remain in hibernation for nearly a month longer than they would if hibernating in other materials.

Table XL also illustrates the influence of temperature upon the duration of the hibernation period, for there is no doubt that it is the temperature prevailing in the exact spot where the individual weevils are hibernating that determines the date of emergence from hibernation. Piles of grass in the open field are warmed by the sun in February and March, and the weevils emerge from them at that time. The shaded places of the forest or swamp are cool and damp, and they do not reach an equivalent temperature until some weeks afterwards, and the weevils consequently emerge later in such places than in the open fields. The bunches of moss are so resistant to heat that even in the hottest days of summer they are very noticeably cooler than the air.

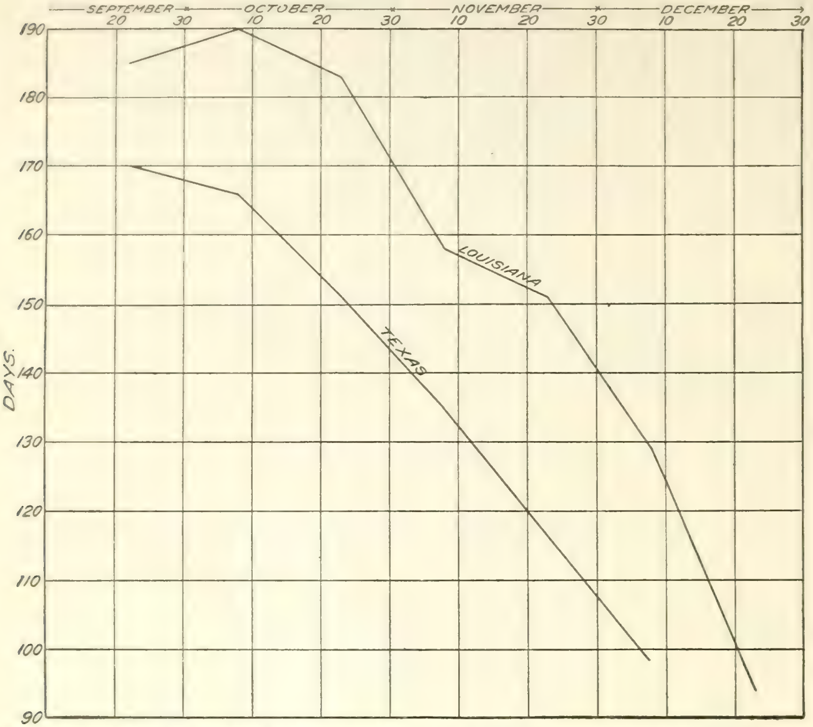

FIG. 22.—Diagram illustrating average length of hibernation period of the boll weevil as related to date of entering hibernation. (Original.)

EMERGENCE FROM HIBERNATION.

TIME OF EMERGENCE.

The time of emergence of the boll weevil from hibernation ranges from February 15 to July 1. It is necessary to discuss the conditions which cause this irregularity. A careful study of all the series of experiments to determine the immediate causes for the first decided impulse to emerge has resulted in the following conclusion: That the time of emergence varies with the total effective temperature and the rainfall. Computing the total effective temperature from January 1 in daily units of mean temperature above the mean of 56° F. (average zero of effective temperature) it is found that approximately 172.6° F. of effective temperature and 5.1 inches of rain are necessary to bring the weevils out of hibernation in comparatively large numbers. If the rainfall is greater than 5.1 inches the necessary effective

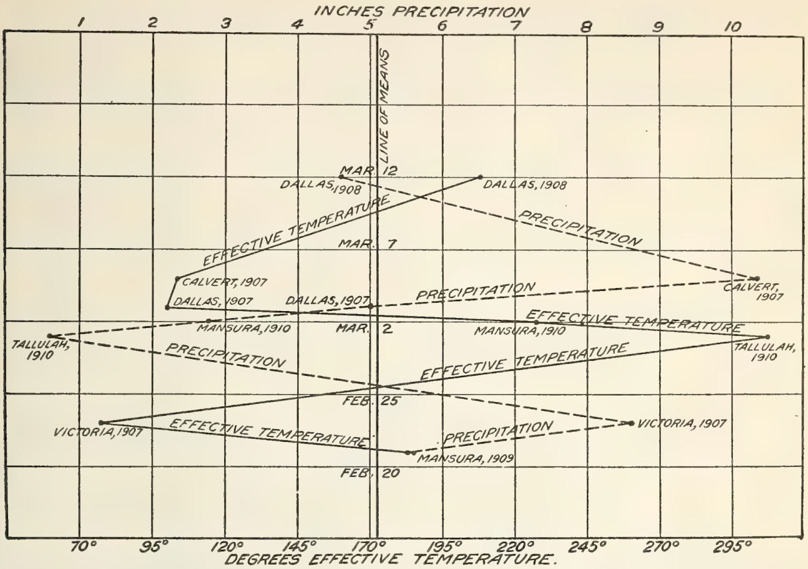

FIG. 23.—Diagram illustrating relations of effective temperature and precipitation to date of beginning emergence of the boll weevil. (Original.)

temperature usually will be less than 172.6° F., and, on the other hand, if the total effective temperature is greater than 172.6° F. the necessary rainfall will usually be less than 5.1 inches. This may be seen by reference to Table XLI and by the diagram (fig. 23). Discrepancies will occur with regard to this formula and will in a large measure be due to the type of shelter or to great irregularities in the climate.

TABLE XLI.—*Relation of effective temperature and precipitation to date of beginning emergence of the boll weevil.*

Place.	Total effective temperature from Jan. 1.	Total precipitation from Jan. 1.	Date of first extensive emergence.
	° *F.*	*Inches.*	
Tallulah, 1910	65	10.5	March 1.
Mansura, 1910	115	7.3	March 2.
Dallas, 1908	160	6.5	March 12.
Dallas, 1907	170	2.2	March 3.
Mansura, 1909	185.5	5.5	February 21.
Victoria, 1907	260	1.3	February 23.
Calvert, 1907	303.7	2.35	March 5.

Figure 23 shows graphically that climate influences the time of beginning emergence. It also has a decided effect upon the subsequent emergence. In Table XLII is shown what effect the daily mean temperature has upon the hibernating weevil.

TABLE XLII.—*The relation of emergence of the boll weevil to increase in temperature at Keatchie, La., and Dallas, Tex., 1906.*[1]

Range of temperatures (° F.).	Keatchie, La.		Dallas, Tex.		Total number of weevils emerged.	Per cent based on grand total emerged.
	Number of weevils emerging.	Per cent of total emergence.	Number of weevils emerging.	Per cent of total emergence.		
43–57	20	2.7	0	0	20	2.5
58–63	52	7.1	2	3.6	54	6.8
64–68	116	16.0	25	45.5	141	17.8
69–73	127	17.5	18	32.7	145	18.5
74–78	309	42.4	10	18.2	319	40.7
79–83	84	11.5	0	0	84	10.7
84–93	20	2.7	0	0	20	2.5
Total	728	100.0	55	100.0	783	100.0

[1] Modified from Bull. 77, Bureau of Entomology, p. 44.

The number of weevils emerging under 57° F. is very small indeed. From that point the emergence increases with the increase in temperature until a majority of the weevils have emerged. Most weevils have been found to leave their winter quarters during a temperature averaging between 64° and 78° F. At Keatchie 75 per cent and at Dallas 96 per cent of the total emergence took place between these limits. At Dallas the largest emergence occurred between temperatures of 64° and 68° F., while at Keatchie the largest emergence occurred between 74° and 78° F. In a preceding paragraph we have shown that higher temperatures are necessary to affect the weevils hibernating in Louisiana, apparently because of the heavier shelter.

RATE OF EMERGENCE.

With a long-continued emergence period it is important to determine whether the rate of emergence is equal at all times or has its periods of retardation and acceleration. Upon charting the percentage of total emergence for each week it was noted that the Texas and Louisiana points differed considerably. On the accompanying diagram (fig. 24) the four Texas series are consolidated to give the average rate, and likewise the four Louisiana series are consolidated, while in Table XLIII the records for each locality are given. It is immediately apparent that the emergence begins much more abruptly in Texas than in Louisiana. In Texas 25 per cent have emerged by March 12, 50 per cent by March 21, 75 per cent by April 8, and 100 per cent not until June 19. On the other hand, in Louisiana 25 per cent have not emerged until March 30, 50 per cent until April 27, 75 per cent until May 16, while 100 per cent will have emerged only by July 3. Herein lies a powerful argument for early planting. With 50 per cent of the weevils emerging after March 21 in Texas and 86 per cent emerging after the same date in Louisiana, or with 75 per cent emerging after April 8 in Texas and 64 per cent yet to emerge after the same date in Louisiana, it becomes evident that every day gained in Texas before March 21 or in Louisiana before April 8 is of immense importance in the fight against the weevil. Even later than these dates every day counts a great deal, because it is apparent that the longer planting is deferred the more weevils will be out to attack the cotton when it comes up.

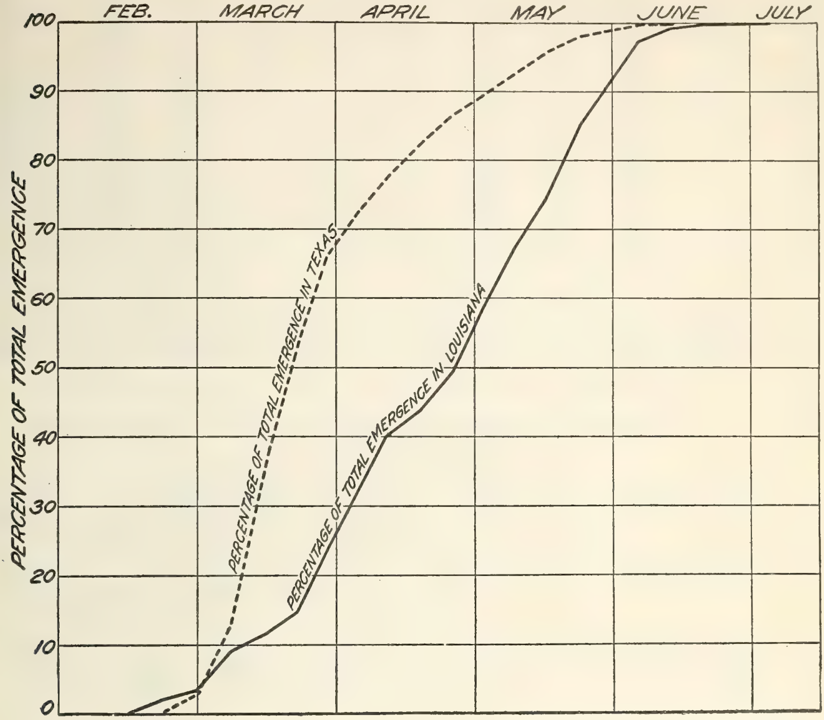

FIG. 24.—Diagram illustrating average rate of emergence of the boll weevil from hibernation in Texas and Louisiana. (Original.)

TABLE XLIII.—*Percentage of total emergence of the boll weevil out at given dates.*

Date.	Keatchie, La., 1906.	Tallulah, La., 1910.	Mansura, La., 1910.	Mansura, La., 1909.	Dallas, Tex., 1908.	Calvert, Tex., 1907.	Dallas, Tex., 1907.	Victoria, Tex., 1907.	Tallulah, La., 1911.
February 21	0.00	0.31	1.64	7.20	0.00	0.00	0.00	0.00	36.95
February 28	.00	.31	3.28	10.61	.00	.00	.00	12.01	36.95
March 7	.00	6.62	10.56	19.22	7.27	22.80	24.48	27.92	39.92
March 14	.00	10.09	15.69	19.73	23.63	31.90	36.36	48.23	63.83
March 21	.00	13.56	21.19	23.24	45.45	44.30	57.14	66.24	70.35
March 28	3.93	23.34	38.05	30.95	55.45	57.20	71.72	79.35	72.52
April 4	6.87	35.95	46.53	38.16	63.63	64.20	75.70	84.16	74.69
April 11	24.54	41.95	49.42	43.87	68.18	70.40	81.28	89.58	81.21
April 18	32.11	46.05	52.41	47.78	74.54	77.70	84.46	93.80	87.73
April 25	40.67	48.89	53.86	56.39	87.27	79.51	85.74	95.02	96.42
May 2	52.73	61.83	60.41	61.30	90.91	82.62	88.62	95.88	96.42
May 9	60.44	70.66	72.35	67.51	91.82	88.73	92.30	97.50	98.59
May 16	72.22	75.39	75.64	75.12	94.55	91.94	95.78	98.36	98.59
May 23	86.41	88.64	84.77	82.43	98.18	94.95	98.76	98.92	98.59
May 30	91.60	93.69	92.77	89.73	98.18	97.56	99.34	99.18	98.59
June 6	97.36	99.05	98.43	96.83	99.09	99.17	99.73	99.90	100.00
June 13	99.19	99.68	99.89	97.83	99.09	99.68	99.88	99.97	100.00
June 20	99.61	99.68	100.00	98.74	100.00	99.99	100.00	100.00	100.00
June 27	99.89	100.00	100.00	99.94	100.00	100.00	100.00	100.00	100.00
July 4	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

The nature of the shelter in which the weevils are hibernating has a decided influence upon the rate of emergence, as is shown in Table XLIV, based upon the experiments of the Louisiana Crop Pest Commission at Mansura, La., in 1909.

TABLE XLIV.—*Effect of nature of shelter upon rate of emergence of the boll weevil, at Mansura, La., 1909.*

Character of hibernating quarters.	Dates by which certain percentages of the surviving weevils were out of hibernation.			
	25 per cent.	50 per cent.	75 per cent.	100 per cent.
Average quarters (cages 5 and 51)	March 19	April 12	May 15	June 27.
Open field (cages A and 5)	March 31	April 29	May 24	June 21.
Swamp (cages Band 51)	April 8	May 20	June 1	June 29.
Moss (cages A and B)	April 13	do	June 2	Do.

It will be noticed that only four cages entered the consideration, cage 5 being average quarters in open field, cage 51 being in average quarters in swamp, cage A being Spanish moss in open field, and cage B being moss in swamp.

SURVIVAL OF HIBERNATED WEEVILS.

The central idea in all the hibernation experiments has been the determination of the percentages of weevils which survive under different conditions and different treatments. In obtaining the facts which have been discussed in the preceding and following paragraphs on hibernation the grand total of 181,932 weevils has been used. With such a large series it is reasonable to suppose that the average percentage of survival must very nearly approximate the normal. This survival in nine series of experiments conducted in seven years at six localities representing the principal climatic, shelter, and other conditions of the infested region has been 7.6 per cent. Table XLV presents the final summaries of each of the nine series.

TABLE XLV.—*Summary of survival of the boll weevil in all the more important experiments.*

Places.	Total number of weevils entering hibernation.	Total number of weevils surviving hibernation.	Percentage of survival.
Keatchie, La., 1906	24,700	731	2.1
Mansura, La., 1909	16,281	3,260	20.0
Mansura, La., 1910	22,179	1,038	4.6
Tallulah, La., 1910	21,835	317	1.4
Tallulah, La., 1911	8,439	46	.5
Five Louisiana series	93,331	5,392	5.7
Dallas, Tex., 1907	32,439	3,464	10.6
Calvert, Tex., 1907	20,430	1,834	8.9
Victoria, Tex., 1907	23,645	3,026	12.8
Dallas, Tex., 1908	12,087	118	.9
Four Texas series	88,601	8,442	9.5
Total of nine series	181,932	13,834	7.6

The highest average percentage of survival for any locality is 20 per cent, at Mansura, La., in 1909, and the lowest average is 0.5 per cent, at Tallulah, La., in 1911. The highest percentage of survival in any cage was 47.72 per cent of 767 weevils, at Mansura, in a cage with average conditions established December 14, 1908. The lowest percentage of survival is no weevils, from 408, at Tallulah, in two cages with average conditions, established November 15, 1910.

RELATION OF FALL DESTRUCTION TO SURVIVAL.

One of the most important recommendations for boll-weevil control is that of early destruction of the cotton stalks. It has long been known that the earlier the stalks are destroyed the less chance the weevils have of surviving. Table XLVI, showing the percentage of emergence by dates of installation, affords an incontrovertible argument in support of this recommendation.

TABLE XLVI.—*Percentage of emergence of the boll weevil, by dates of installation.*

Place.	Sept. 16–30.	Oct. 1–15.	Oct. 16–31.	Nov. 1–15.	Nov. 16–30.	Dec. 1–15.	Dec. 16–31.
Texas points.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Dallas, 1907		2.61	6.67	20.57	4.36		
Calvert, 1907		3.15	3.98	10.33	2.65		
Victoria, 1907			6.17	17.69	16.22		
Dallas, 1908	0.23	.39	2.8	1.68	5.26		
Texas, weighted average percentage	.23	2.33	5.62	15.42	16.05		
Total weevils installed	5,213	7,729	27,806	30,431	12,173		
Louisiana points.							
Keatchie, 1906					2.71	3.23	0.8
Mansura, 1909	2.7	3.31	23.9	23.8	24.56	43.23	37.06
Mansura, 1910	.23	1.31	6.58	9.95	6.31	6.79	
Tallulah, 1910	.34	2.23	1.16	1.53	2.4	.00	
Tallulah, 1911		1.15	.54	.00		.00	
Louisiana, weighted average percentage	.37	2.00	8.04	8.82	6.07	10.65	12.61
Total weevils installed	8,186	14,218	24,464	9,620	24,252	10,208	1,483
Grand weighted average percentage	0.31	2.07	6.58	14.26	9.00	10.65	12.61
Total weevils installed	13,399	21,947	52,270	40,051	36,425	10,208	1,483

Converted into terms of the number of weevils in every thousand which would survive the winter if stalks were destroyed on a given date, we can see the force of Table XLVI. It is even more evident from the arrangement of the data given below in Table XLVII.

TABLE XLVII.—*Number of boll weevils in each 1,000 which would have survived destruction of stalks on a given date.*

Date of destruction.	In Texas.	In Louisiana.
September 16–30	2	3
October 1–15	23	20
October 16–31	56	80
November 1–15	154	88
November 16–30	160	60
December 1–15	(?)	106
December 16–31	(?)	126

RELATION OF SHELTER TO SURVIVAL.

It has already been stated that the density of the shelter has a bearing upon the survival. This is best shown by the following records (Table XLVIII):

TABLE XLVIII.—*Relation of shelter of boll weevils to their survival.*

Place.	Date installed.	Weevils.	Shelter.	Survival.
				Per cent.
Mansura, La	October 26	2,436	Average	20.00
Do	do	2,158	Moss	37.76
Victoria, Tex	October 28	2,375	Average	5.61
Do	November 6	2,850	Moss	23.65
Do	November 10	2,850	Average	12.70

RELATION OF CLIMATE TO SURVIVAL.

Another important consideration in determining the causes for high or low survival is the climate. Some of the principal relationships are brought out in Table XLIX below:

TABLE XLIX.—*Relation of climate to survival of boll weevils in hibernation.*

Place and year.	Description.	Number of weevils.	Per cent of survival.	Periods of emergence.	Rainfall and temperature, Oct. 1–Mar. 15.		
					Rainfall.	Absolute minimum.	Total degrees below 32.
					Inches.	°*F.*	°*F.*
Tallulah, La., 1910–11.	10 cages, variety of shelter, installed Oct. 15–Dec. 1.	8,439	0.5	Feb. 15–June 4	8.30	9.5	199.5
Dallas, Tex., 1907–8.	9 cages, variety of shelter, Sept. 21–Nov. 18.	12,087	.9	Feb. 19–June 16	22.61	15.0	233.0
Tallulah, La., 1909–10.	19 cages, great variety of shelter, Sept. 16–Dec. 14.	21,835	1.4	Feb. 15–June 27	19.34	13.0	378.5

TABLE XLIX.—*Relation of climate to survival of boll weevils in hibernation*—Con.

Place and year.	Description.	Number of weevils.	Per cent of survival.	Periods of emergence.	Rainfall and temperature, Oct. 1–Mar. 15.		
					Rainfall.	Absolute minimum.	Total degrees below 32.
					Inches.	°*F.*	°*F.*
Keatchie, La., 1905–6.	18 cages, variety of shelter (1 bare), installed Nov. 18–Dec. 18.	24,700	2.1	Mar. 22–June 28..	18.87	21.0	91.0
Mansura, Tex., 1909–10.	19 cages, great variety of shelter, Sept. 16–Dec. 14.	22,179	4.6	Feb. 15–June 15..	15.37	19.5	151.5
Calvert, Tex., 1906–7.	10 cages, variety of shelter, Oct. 1–Dec. 10.	19,408	8.9	Mar. 4–July 1.....	11.87	26.0	47.0
Dallas, Tex., 1906–7.	10 cages, variety of shelter, Oct. 13–Dec. 6.	30,864	10.6	Mar. 1–June 19...	8.52	22.0	145.0
Victoria, Tex., 1906–7.	10 cages, variety of shelter, Oct. 25–Nov. 29.	22,463	12.8	Feb. 28–June 15..	11.25	27.0	5.0
Mansura, La., 1908–9.	19 cages, great variety of shelter, Sept. 28–Dec. 21.	16,281	20.0	Feb. 21–June 29..	10.44	23.0	81.0

One of the most striking features of Table XLIX is the disparity between the percentage of survival through the six winters considered. A special effort has been made to discover the factors that cause this disparity. Among those that have been considered are the absolute minimum temperature, the daily accumulated degrees below 32 during the hibernation season, the number of times a temperature below 32° was reached, and the rainfall. Contrary to our expectations, it appears that the number of times the temperature descends below 32° has no direct effect. However, there seems to be a direct relation between the absolute minimum temperature and the rainfall, taken together, and the percentage of survival. As the absolute minimum ascends and the rainfall decreases the survival seems to increase. The greatest survival (Mansura, La., 1908–9) was accompanied by the third highest minimum temperature and the third lowest rainfall during the hibernation season. In the same way the next to the highest survival (Victoria, Tex., 1906–7) was accompanied by the highest absolute minimum temperature and the fourth lowest rainfall. Conversely, the lowest survival (Tallulah, La., 1910–11) was accompanied by the lowest absolute minimum temperature and the lowest rainfall. The next to the lowest survival (Dallas, Tex., 1907–8) was accompanied by the third lowest absolute minimum temperature and the highest rainfall. It thus appears that a moderately cold winter, with temperature frequently near the zone of fatal temperatures and excessive precipitation, is very unfavorable for the weevil, but a winter with little precipitation and a temperature within the zone of fatal temperatures is by far the most fatal. Conversely, a winter with temperatures always above 20° and moderate precipitation is the most favorable for the weevil.

Certain climatic phenomena are likely to occur which will emphasize still more the effects produced by extreme cold and great precipitation. At Tallulah, La., in 1910–11, the early freeze on October 29 cut off the food supply and was followed by warm temperatures in November which required feeding. The minimum experienced in January completed the control and was low enough to counteract the small precipitation.

LONGEVITY OF HIBERNATED WEEVILS.

From the beginning of the hibernation experiments in 1905 it has been the custom to place the emerging weevils in rearing jars or cages to determine the average and maximum longevity with and without food. The data obtained have a bearing upon the proper time for planting and upon other practical points. In these experiments 9,295 weevils have been used, as shown in Table L. The fed weevils were furnished cotton squares as soon as they became available. Before that time they were given fresh cotton leaves daily. The unfed series was supplied with water only. Both series were placed in small cages where general conditions closely approaching those in nature were maintained. It should be especially noted that fed weevils show over double the longevity of unfed weevils throughout the season.

TABLE L.—*Longevity of hibernated boll weevils after emergence.*

Place.	Unfed series.			Fed series.		
	Number of weevils.	Longevity.		Number of weevils.	Longevity.	
		Maximum.	Average.		Maximum.	Average.
		Days.	*Days.*		*Days.*	*Days.*
Keatchie, La., 1906	412	62	17.11			
Dallas, Tex., 1907	2,179	90	12.50	901	130	38.20
Calvert, Tex., 1907	1,079	48	8.07	715	118	30.00
Victoria, Tex., 1907	1,360	44	8.20	1,349	86	14.70
Mansura, La., 1909	261	44	11.09	360	36	10.42
Natchez, Miss., 1909	4	19	8.75	36	25	12.20
Mansura, La., 1910	175	28	8.78	146	81	36.50
Tallulah, La., 1910	179	21	5.70	121	105	22.30
Tallulah, La., 1911	8	12	7.25	10	25	13.30
Total	5,657			3,638		
Maximum		90	17.11		130	38.20
Weighted average			10.55			24.20

It will be noted that the records of longevity of weevils after emergence from hibernation referred to above are based upon specimens that had passed the winter in artificial hibernation cages. However, a number of observations have been made upon the longevity of weevils which pass the winter under natural conditions in the field. For instance, March 1, 1906, a number of weevils were collected from cotton bolls at Brenham, Tex. These were placed in small cages and observed daily. The last one died on May 31. Naturally the time this weevil was deprived of food the preceding fall is not known, but it must have been prior to December 1, as the frosts had killed all cotton at Brenham by that date. Assuming that it entered hibernation on December 1, it lived six months without food. In another case weevils collected in the field in the spring at Calvert, Tex., lived without food as late as June 8. This gives a duration of life without food of six months and twelve days. Similar observations indicate clearly that the longevity of weevils that pass the winter in artificial cages is a proper index to the longevity of those which pass the winter in the field.

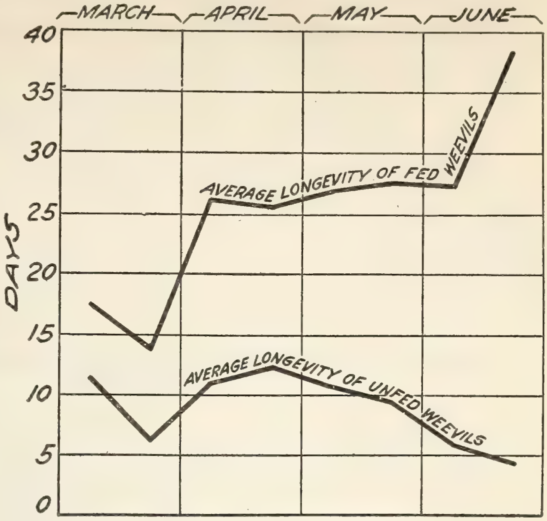

FIG. 25.—Diagram illustrating average longevity of boll weevils after emerging on a given date. (Original.)

It has become quite apparent from a study of the records that the longevity of weevils provided with food is considerably greater with weevils emerging in June than with those emerging in March, while, on the contrary, with unfed weevils the longevity decreases with the lateness of emergence. (Table LI.)

The diagram (fig. 25) illustrates the above statement graphically.

TABLE LI.—*Latest dates of death of hibernated boll weevils.*

Time of emergence.	Unfed weevils.		Weevils fed foliage.		Weevils fed squares.	
	Mansura, La., 1910.	Tallulah, La., 1910.	Mansura, La., 1910.	Tallulah, La., 1910.	Mansura, La., 1910.	Tallulah, La., 1910.
Feb. 15–28	Mar. 18	....	....	....	....	....
Mar. 1–15	Apr. 13	Apr. 1	....	....	....	....
Mar. 16–31	Apr. 20	Apr. 12	June 20	....	....	....
Apr. 1–15	Apr. 28	Apr. 28	July 5	June 21	....	....
Apr. 16–30	May 13	May 21	June 28	June 18	....	....
May 1–15	May 29	June 1	July 15	July 15	....	....
May 16–30	June 12	June 15	July 12	July 26	....	Sept. 13
June 1–15	....	June 27	July 29	July 7	July 19	July 1
June 15–30	....	....	....	....	....	Aug. 31
Entire season	June 12	June 27	July 29	July 26	July 19	Sept. 13

MAXIMUM LENGTH OF LIFE.

In connection with Table LI it will be noticed that the latest known recorded death of a hibernated weevil is September 13. This fact, taken in conjunction with Table LII, showing the maximum longevity of weevils from the time of entering hibernation to death, is of great interest. The maximum longevity of 335 days, or 11 months, gives proof of the wonderful vitality of the boll weevil.

TABLE LII.—*Longevity of hibernated boll weevils from installation to death.*

Place.	Condition.	Longevity.	
		Average.	Maximum.
		Days.	*Days.*
Mansura, La., 1910	Unfed	158	226
Tallulah, La., 1910	....do	169	243
Mansura, La., 1910	Fed foliage	206	256
Tallulah, La., 1910	....do	221	272
Mansura, La., 1910	Fed squares	257	267
Tallulah, La., 1910	....do	262	335

RELATION OF EMERGENCE AND LONGEVITY TO TIME OF PLANTING.

The data that have been presented show the extreme importance of early planting as a means of averting damage by the boll weevil. Early planting takes advantage of the portion of the season when the weevils are present in the fields in smallest numbers. The longer planting is deferred the greater the number of weevils which will have emerged. The advantage of an early crop has been shown in many experiments by the Bureau of Entomology and by practical cotton planters. On the other hand, the experience in late plantings has been disastrous. The obvious explanation is in the prolonged period of emergence and the remarkable ability of the weevils to live without food after emergence. This topic will receive additional treatment under the heading of "Repression."

NATURE OF WEEVIL ACTIVITY FOLLOWING EMERGENCE FROM HIBERNATION.

In the section dealing with the spring movement we have discussed the early search of the weevils for food. There are certain points connected with the spring movements, however, which are intimately related to hibernation, and these will be dealt with here.

[1] In following the activity of emerged weevils at Dallas, Tex., certain specimens were marked in such a way as to make it possible to recognize them individually, and the weevils were allowed to remain practically undisturbed in the section where they had spent the winter. In making the daily examinations record was kept of the appearance or disappearance of each individual weevil. No food was supplied in any of the sections until toward the close of the experiments in May, when seed was planted and cotton began growing before the last weevils emerged. A majority of the weevils were seen a second time, and some disappeared and reappeared as many as eight times. The longest period between the first and second appearance of any individual was 43 days.

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[1] From Bull. 77, Bureau of Entomology, pp. 50, 51.

TABLE LIII.—*Intermittent activity of unfed boll weevils after emergence, at Dallas, Tex., 1906.*

Number of weevils seen—								Weevils "rehibernated"—						Average survival, number of days.
								Once.		Twice.		Three times.		
Once.	Twice.	Three times.	Four times.	Five times.	Six times.	Seven times.	Eight times.	Number.	Days.	Number.	Days.	Number.	Days.	
46	26	15	11	6	2	2	1	17	8.7	6	7.2	2	3.5	6.8

The observations recorded in Table LIII show conclusively that weevils may leave their winter quarters during warm days and, failing to find food, they may again become quiet and emerge again after a considerable interval. This fact has an important bearing upon the proposition which is frequently advanced by planters of starving the weevils in the spring by deferring the time of planting. While many weevils might perish in this way, it is certain that many more would be able to survive and reappear at intervals, so that there would be plenty of weevils to infest the crop, even though this might be planted as late as is possible to secure any yield.

Other observations were made upon the intermittent activity of unfed weevils during the spring of 1906. Weevils from Calvert, Victoria, and Brenham, Tex., were tested. The weevils from Calvert and Victoria had been confined in hibernation cages throughout the winter. Those from Brenham were collected in the field early in March. None of these weevils had tasted food after emergence. The results are shown in Table LIV. In this table the date of death, unless otherwise indicated, is considered as having been the middle date between the last examination at which a weevil was found alive and that at which it was found dead.

TABLE LIV.—*Intermittent activity of unfed emerged boll weevils, 1906.*[1]

Locality.	When collected.	When put in hibernation.	When removed from hibernation.	When rehibernated.	Weevils put in rehibernation.	Date of first examination.
	1905	1905	1906	1906		
Calvert, Tex.	Nov. 25	Nov. 27	Apr. 19	Apr. 23	20	May 10
Victoria, Tex.	Nov 7, 13 Dec. 11	Nov. 7, 13 Dec. 11	Apr. 6	Apr. 16	7	Apr. 24
	1906					
Brenham, Tex.	Nov. 1	....	Mar. 1	Mar. 7	8	May 11

Locality.	Weevils surviving.	Date of second examination.	Weevils surviving.	Date of third examination.	Weevils surviving.	Date of death of longest survival.	Average length of life in rehibernation.
							Days.
Calvert, Tex.	10	May 22	6	June 8	0	June 8	30.4
Victoria, Tex.	3	May 10	0	....	....	May 10	19.1
Brenham, Tex.	2	May 23	1	May 31	0	May 31	67.4

[1] From Bulletin 77, Bureau of Entomology, p. 52.

The records for Calvert and Brenham show a very remarkable power of endurance in some weevils, the average survival for the two lots of 20 and 8 weevils being over 30 and 60 days, respectively.

NATURAL CONTROL.

Considerable attention has been given to the study of the natural forces which control the boll weevil. These studies have revealed a large amount of important data, some of which have been used in several bulletins. In the present publication it is possible to give only a summary of the most important results.

In general, the natural agencies which control the boll weevil may be classified as climatic (consisting principally of heat which kills directly and also indirectly by rendering the food supply unsuitable, and dryness, the effects of which are intermingled with those of heat), plant resistance, parasites and other insect enemies, diseases, and birds. Each of these agencies will be discussed separately, but a general summarization may be of value. Table LV is a summary of the observations made in the years 1906 to 1909 on weevil stages from many localities. It deals with the mortality of immature stages from all causes exclusive of plant proliferation.

TABLE LV.—*Annual mortality of immature boll weevils in all classes of cotton forms. 1906–1909.*

Year.	Total forms examined.	Total stages found.	Total stages dead.	Number stages killed by—			Percentages of mortality due to—			
				Climate.	Predators.	Parasites.	All causes.	Climate.	Predators.	Parasites.
1906	100,644	40,073	22,353	10,078	10,547	1,728	55.81	25.15	26.31	4.31
1907	21,980	13,405	7,275	3,896	2,263	1,116	54.27	29.06	16.88	8.32
1908	72,234	29,546	13,103	6,268	3,878	2,957	44.34	21.21	13.12	10.00
1909	27,857	11,653	4,863	3,012	1,231	620	41.73	25.84	10.56	5.32
1906–1909	222,715	94,677	47,594	23,254	17,919	6,421	50.26	24.56	18.92	6.78

Inasmuch as the material used in making the examinations was derived from many sources and in different proportions each year, a system of weighting the different kinds of material was devised. Table LVI presents a summarization of this weighting in terms of percentages of mortality:

TABLE LVI.—*Weighted average mortality of the boll weevil, 1906–1909, due to various causes.*

Year.	Proliferation.[1]	Climate.	Predation.	Parasitism.	Total.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1906	12.42	24.39	24.85	2.94	64.61
1907	12.42	28.16	16.18	3.83	60.61
1908	12.42	17.83	11.77	6.34	48.37
1909	12.42	23.01	10.92	2.63	48.99
1906–1909	12.42	24.45	15.93	3.93	56.73

[1] The average determined in 1906 (see Bull. 59, Bureau of Entomology) is used to apply to other years.

The extensive series of examinations tabulated above (Table LVI) were made upon immature weevils in all conditions of squares and bolls, the principal of which are known as hanging dry squares, fallen squares, hanging dry bolls, and fallen bolls. The conditions in these four classes of material vary greatly as does the mortality, as is shown in Table LVII. The apparent discrepancy between the totals in Table LVII and in Table LVI is due to the admission of other minor classes of material in the first table. This table (LVII) also excludes mortality from plant proliferation.

TABLE LVII.—*Mortality of immature boll weevils in various classes of cotton forms, 1906–1909.*

Class of infested forms.	Total forms examined.	Total stages found.	Total stages dead.	Number stages killed by—			Percentages of mortality due to—			
				Climate.	Predators.	Parasites.	All causes.	Climate.	Predators.	Parasites.
Fallen squares	107,293	63,985	34,403	17,596	13,958	2,849	53.76	27.50	21.81	4.45
Hanging squares	24,683	14,390	7,084	2,543	1,745	2,796	49.22	17.67	12.19	19.43
Hanging bolls	41,738	8,737	3,328	1,709	1,054	565	38.09	19.56	12.06	6.47
Fallen bolls	46,200	6,825	2,375	1,128	1,148	99	34.79	16.52	16.80	1.45
All classes	219,914	93,937	47,190	22,976	17,905	6,309	50.23	24.45	19.06	6.71

Still another extremely important aspect of this large series needs to be shown. This is the geographical differences in the control by climate, predators, and parasites.

TABLE LVIII.—*Average mortality of immature boll weevils in various classes of cotton forms by States, 1906–1909.*

Class of forms and State.	Total forms examined.	Total stages found.	Total stages dead.	Stages killed by—			Mortality due to—			
				Climate.	Predators.	Parasites.	All causes.	Climate.	Predators.	Parasites.
Fallen squares.							*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
Arkansas	374	162	62	43	17	2	38.27	26.54	10.49	1.23
Louisiana	28,204	15,177	4,895	1,990	2,243	562	32.25	13.11	14.77	3.70
Mississippi	4,216	2,661	1,070	416	263	391	40.21	15.63	9.88	14.69
Oklahoma	657	442	238	100	117	21	53.84	22.62	26.47	4.75
Southwest Texas	2,757	1,390	390	186	152	52	28.06	13.38	10.93	3.74
Southern Texas	38,007	25,063	16,965	8,547	7,377	1,041	67.68	34.10	29.43	4.15
East Texas	825	464	248	136	107	5	53.44	29.31	23.06	1.07
Central Texas	14,879	7,628	4,233	2,386	1,602	245	55.49	31.28	21.00	3.21
Northeast Texas	10,318	6,497	3,439	1,812	1,347	280	52.93	27.89	20.73	4.30
North-Central Texas	7,066	4,501	2,863	1,980	633	250	63.60	43.99	14.06	5.55
Hanging squares.										
Arkansas	1,612	1,144	494	188	60	246	43.18	16.43	5.24	21.50
Louisiana	8,601	5,184	2,182	881	651	650	42.09	16.99	12.55	12.53
Mississippi	784	499	182	41	34	107	36.47	8.21	6.81	21.44
Oklahoma	100	63	26	6	0	20	41.27	9.53	0.00	31.74
Southwest Texas	89	46	24	6	2	16	52.10	13.00	4.30	34.70
Southern Texas	5,740	3,626	1,937	727	496	714	53.41	20.04	13.67	19.69
East Texas	192	135	10	5	1	4	7.40	3.70	0.74	2.96
Central Texas	2,094	1,052	703	253	208	242	66.82	24.04	19.75	22.98
Northeast Texas	4,044	1,667	887	290	211	386	53.80	17.39	12.66	23.15
North-Central Texas	1,992	1,141	766	196	88	492	67.13	17.17	7.71	43.12

Although the grand total of the examinations shows a higher mortality due to fallen squares than to hanging squares, it is noticeable that the mortality in hanging squares is greater in Arkansas, Louisiana, southwestern, central, northeastern, and north-central Texas, and less in Mississippi, Oklahoma, and southern and eastern Texas.

As shown in Table LVIII, the highest mortality in fallen squares is 67.68 per cent in southern Texas and the lowest 28.06 per cent in southwestern Texas. In hanging squares the highest mortality is 67.13 per cent in north-central Texas and the lowest, 7.40 per cent, in eastern Texas.

Climatic control is highest in fallen squares in north-central Texas, at 43.99 per cent, and lowest in Louisiana, at 13.11 per cent, while in hanging squares it reaches 24.04 per cent only in central Texas and is as low as 3.70 per cent in eastern Texas.

Predatory control in fallen squares is highest in southern Texas, at 27.43 per cent, and lowest in Mississippi, at 9.88 per cent, while in hanging squares its highest average is 19.75 per cent in central Texas and its lowest no per cent in Oklahoma.

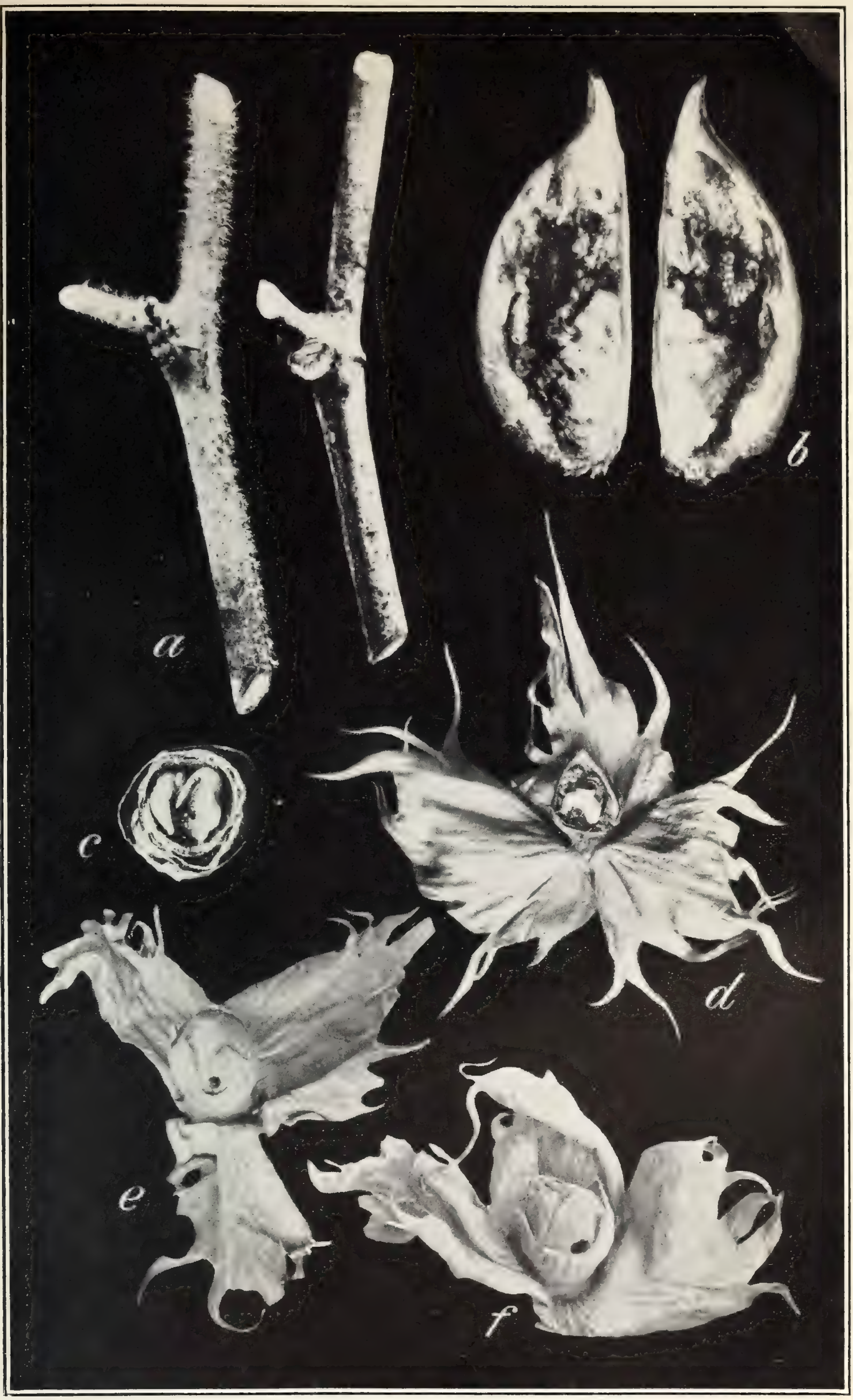
Parasitic control in fallen squares is highest in Mississippi, at 14.69 per cent, and lowest in eastern Texas, at 1.07 per cent. On the other hand, in hanging squares it is highest in north-central Texas, with 43.12 per cent, and lowest in eastern Texas, with 2.96 per cent.

In fallen squares it is generally the case that over half of the mortality is due to climate, but in Louisiana, Mississippi, Oklahoma, and southwestern Texas insect control is greater than climatic. In hanging squares the insect control is invariably greater than climatic control, and in Mississippi, Oklahoma, and southwestern and north-central Texas parasitic control alone is greater than the climatic plus the predatory control. It was shown in the table comparing the total mortality in all classes of forms (Table LVII) that the weighted average mortality due to insects was 25.77 per cent, as against 24.45 per cent due to climate. All of this evidence is cited to show that in reality the insect enemies produce a very large proportion of the mortality of the boll weevil and should therefore be encouraged in every way possible. Of course, it is evident that climatic control is even superior, because of the influences it brings to bear upon every phase of the weevil's existence.

Regional comparisons such as have been made above are of the greatest importance in determining what factors in natural control need to be given the greatest encouragement by cultural expedients or otherwise.

CLIMATIC CONTROL.

From almost every viewpoint the climatic control of the boll weevil is the most important which this insect experiences. The weevil reacts to a multitude of conditions of temperature and humidity. The time of entrance into hibernation, the length of the hibernation period, the time of emergence from hibernation, the length of the various immature stages, the rate of oviposition, and even the proportion of sexes are profoundly affected by these agencies. In many cases their effects are not direct. They may affect the weevil indirectly through the cotton plant. For example, drought may interfere with the fruiting of the cotton plant and thus deprive the weevils of food.



NATURAL CONTROL OF THE BOLL WEEVIL.

a, Pilose and nonpilose stems of cotton; *b*, larva of boll weevil crushed by proliferation; *c*, pupa of *Catolaccus incertus* on pupa of cotton boll weevil; *d*, larva of *Microbracon mellitor* attacking boll-weevil larva; *e, f*, holes gnawed by *Solenopsis geminata* in effecting entrance into infested squares. (Original.)

The most conspicuous illustration of the climatic control of the weevil lies in the failure of the pest to establish itself in the drier portions of Texas. For several years multitudes of weevils have flown from the more humid portions of Texas to the west, where the climate is drier. In fact, every year there has been a large inflow of weevils into this region. Every season, however, the conditions have practically immediately prevented the establishment of the weevil. The most important factor has been dryness, but there are others that must be considered. Among them is the fact that there is comparatively little winter protection for the insect. In addition, an indirect result of small precipitations is the growth of cotton plants of only small size. This results in a small amount of shade and thus augments the direct effect of heat and dryness upon the infested squares which fall to the ground.

Frequently the effects of climate act upon the enemies of the boll weevil. This is the case where heat destroys the weevils and their parasites in squares that fall to the ground. In several cases, however, heat increases the effectiveness of the enemies of the weevil. A striking example of this was observed on September 2, 1911, by Mr. J. D. Mitchell, of the Bureau of Entomology. A succession of days in which the temperature was very high and the air exceedingly dry caused the premature opening of many cotton bolls in the vicinity of Victoria, Tex. Prior to this time the weevils had destroyed practically all of the squares, and many immature stages were to be found in the bolls thus forced open. In such instances the exposed immature stages of the weevil were subjected to two important destructive agencies. Heat killed many that became exposed to the air, and the ants were able to reach not only those that were exposed, but others inside of the partially opened bolls. If the bolls had not opened, such weevils would have been beyond the reach of the ants. As it was, the climatic conditions not only directly destroyed large numbers of weevils in a situation where climatic factors rarely affect them, but also greatly increased the effectiveness of another unrelated factor of control.

CLIMATIC INFLUENCES ON VITALITY AND ACTIVITIES.

In the preceding pages numerous effects of climate upon the development and activities of the boll weevil have been pointed out, but these must be summarized in order to show how intimately connected the climate is with every phase of the weevil's life. It appears that the movements of the weevil are sluggish or active in accordance with the nature of the day, cloudy days or low temperatures always causing them to be more sluggish. The number of feeding punctures per square decreases with increases in temperature, and the time before falling of a punctured square also decreases with higher temperatures. In like manner the length of life of the weevil decreases. The age of beginning copulation and the age of beginning oviposition are both increased by decreases in temperature. The activity in oviposition, which is found to begin at 75° F., is greatest in the hottest time of the day, cloudy days causing the oviposition to be less active. The number of eggs per day increases with the temperature and varies for any given temperature with the humidity. The entire period of development increases as the temperature and atmospheric humidity decrease.

The number of generations decreases with the mean temperature and mean humidity.

Hibernation seems to begin at mean temperatures between 56° F. and 60° F., but is hastened by high humidity. Cold nights followed by warm, still days seem to stimulate the weevils to considerable activity in the fall, evidently warning them to seek hibernation quarters. The period of entrance into hibernation is much more rapid as the mean humidity and mean temperature become lower. The emergence of the weevil is in like manner influenced by the temperature, but it must be considered that the actual temperature experienced by the weevil is that which affects the emergence. The time of emergence apparently depends upon an accumulation of a certain amount of effective temperature and a certain amount of rainfall, but if more than the necessary temperature accumulates less rainfall will be needed, and vice versa. The majority of weevils emerge at mean temperatures between 64° F. and 78° F. The percentage of survival seems to decrease as the absolute minimum temperature decreases and the rainfall increases.

The foregoing statements are conclusions based in some cases upon more or less fragmentary information, but in other cases they may almost be considered as laws of climatic control.

FIELD OBSERVATIONS ON MORTALITY DUE TO HEAT AND DRYNESS.

Heat and dryness affect the weevil in a very simple manner. Unless the square remains moist the food supply becomes unsuitable. In other cases the heat itself causes death directly. Therefore, the hotter and drier the ground upon which the infested square falls, the more certain is the death of the weevil.

In the years 1906 to 1909 an exhaustive study was made of the effects of various climatic and other agencies which control the boll weevil. In this work 222,715 cotton forms (including bolls and squares) were collected by agents of the Bureau of Entomology at 65 localities in Texas, 26 in Louisiana, 7 in Oklahoma, 6 in Arkansas, and 6 in Mississippi. Careful laboratory observations were made to determine the mortality due to heat or dryness and to other factors.

By reference to the series of general tables (LV–LVIII) at the beginning of the discussion of natural control it will be noticed that climatic control kills practically one-fourth of the developing stages, the average for the four years in which records were made being 24.56 per cent, which was slightly surpassed by the total insect control. The highest average climatic control was obtained in 1907, being 29.06 per cent, while in 1908 it averaged only 21.21 per cent.

In rearranging the data to ascertain the condition in which the control was greatest we find the following results: Fallen squares, 27.50 per cent; hanging dry bolls, 19.56 per cent; hanging dry squares, 17.67 per cent; and fallen bolls, 16.52 per cent.

The geographical distribution of climatic control is very interesting. In fallen squares the various sections ranked as follows: North-central Texas, 43.99 per cent; southern Texas, 34.10 per cent; central Texas, 31.28 per cent; eastern Texas, 29.31 per cent; northeastern Texas, 27.89 per cent; Arkansas, 26.54 per cent; Oklahoma, 22.62 per cent; Mississippi, 15.63 per cent; southwestern Texas, 13.38 per cent; Louisiana, 13.11 per cent.

In hanging squares we find a somewhat different arrangement of the sections: Central Texas, 24.04 per cent; southern Texas, 20.04 per cent; northeastern Texas, 17.39 per cent; north-central Texas, 17.17 per cent; Louisiana, 16.99 per cent; Arkansas, 16.43 per cent; southwestern Texas, 13 per cent; Oklahoma, 9.53 per cent; Mississippi, 8.21 per cent; and eastern Texas, 3.70 per cent.

In many of the records made during 1906 it became evident that certain cultural practices greatly favored the amount of control by heat and dryness. The wider the rows, the greater the amount of sunlight which strikes the ground. Consequently the fields with wide rows or in which the stand was imperfect showed the greatest mortality. In a similar way, fields in which were varieties with comparatively small amounts of leafage showed greater mortality due to heat and dryness. It did not become apparent, however, from the observations made, that the direction in which the rows ran made any material difference in the mortality.

The difference between the various sections in the mortality in fallen squares is especially conspicuous. This is due undoubtedly primarily to the greater precipitation in the sections with low mortality, which, by keeping the ground more or less moist, prevents such temperatures at the surface as are frequently reached in Texas. The greater rainfall in Louisiana also undoubtedly has an indirect effect. In that State the additional rainfall causes the cotton plants to grow to a large size and to shade the ground more than is the case in Texas, thus preventing the sun from reaching the squares on the ground. The differences in hanging squares are not quite so conspicuous, but are probably due to some extent to atmospheric humidity, density of foliage, and other similar factors.

Equally interesting results were obtained in 1906 with reference to the effect of heat and dryness upon the different stages of the boll weevil. It was found that the mortality in the larval stage amounted to 52 per cent, in the pupal stage to 18 per cent, and in the adult stage to 6 per cent. Nearly 70 per cent of all the mortality caused by heat and dryness occurs, therefore, during the larval stage.

Table LIX illustrates the percentage of stages killed during the warm months of the year by high temperatures and is based upon all of the examinations made during the years 1906 to 1909, inclusive.

TABLE LIX.—*Weighted average heat control of immature stages of the boll weevil, by months, Texas, Louisiana, Oklahoma, Arkansas, and Mississippi.*

Month.	Forms examined.	Stages found.	Per cent killed by heat and drying.
May	100	56	7.20
June	16,930	10,708	28.33
July	43,059	21,758	25.61
August	80,923	33,170	24.62
September	37,378	17,107	22.87
October	17,344	8,283	16.59
Total	195,734	91,082	23.80

Many illustrations are available to show the powerful effect of heat and dryness in the reduction in the numbers of boll weevils in cotton fields. The action of this agency is so powerful that it may check the weevils in a single season so that a crop may be obtained. This was shown in a field which was under observation in Victoria County, Tex., in 1906. It was found in April that a very large number of hibernated weevils appeared in the field. This month was reasonably moist, so that the cotton germinated promptly and made a quick growth. The month of May, however, showed a decided deficiency in precipitation, being more than 3 inches below the normal for the month. This checked the weevil at the time the first infested squares began to drop. The control continued during the month of June, which also showed 3 inches less than the normal rainfall. These conditions resulted in such a checking of the weevils by June that the cotton plants were able to put on a large number of squares. The month of July showed a precipitation above the normal, which caused the plants to grow rapidly. The setback experienced by the weevils, however, during the preceding dry period was so great that they were unable to overtake the production of fruit, so that a yield of about one-fourth of a bale per acre was obtained.

Examples of such complete control within a single season are not common. It frequently happens that a drought continues so long that the plants are seriously affected. In general, however, the plants can recover more rapidly from a drought than the weevil. This results in an advantage to the crop from even a short drought. Of course the advantage becomes greater as the drought is prolonged, provided it is not prolonged to a point where it seriously affects the growth of the plants. Examples of the control of the weevil in one season from heat and dryness of the preceding season are common. Table LX shows a striking instance of this kind. It will be seen that the effects of the drought of 1902 extended into the following season and brought about a marked increase in production. By the following year (1904) the recovery of the weevils from the drought of 1902 was indicated by a decreased production of cotton.

TABLE LX.—*General illustration of drought control of the boll weevil, Nueces County, Tex., 1901–1904.*

Year.	Rainfall.				Temperature.				Cotton production, Nueces County, equivalent in 500-pound bales.
	Annual.		Mar. 1–Aug. 31.		Annual.		Mar. 1–Aug. 31.		
	Mean average.	Departure from normal.	Mean average.	Departure from normal.	Mean average.	Departure from normal.	Mean average.	Departure from normal.	
	Inches.	*Inches.*	*Inches.*	*Inches.*	°*F.*	°*F.*	°*F.*	°*F.*	
1901	17.49	−11.90	6.74	− 7.42	70.7	0.0	76.2	+0.83	601
1902	22.22	− 7.98	5.57	− 7.39	71.5	+1.4	77.3	+1.85	480
1903	36.92	+ 6.72	25.97	+11.38	69.1	− .9	74.5	− .9	4,099
1904	28.54	− 1.66	13.56	+ .83	70.5	+ .4	76.0	+ .5	1,556

GENERAL DISCUSSION OF THE RELATIONS OF TEMPERATURE TO THE BOLL WEEVIL.

Our studies of the boll weevil lead us to the conclusion that there is a certain degree of temperature above which, under any condition of humidity, no individuals can exist even for a limited time. This point is known as the *maximum fatal temperature.* Below this there is a zone of varying width of temperatures which may be fatal in cases of long exposure or under certain conditions of humidity or insect vitality. This may be known as the *upper zone of fatal temperatures.* Below the zone of fatal temperatures is a zone of temperatures which, when continuing for any length of time, force the insects to shelter. This zone may therefore be fitly called the *zone of æstivation,* and it must be understood that the relative humidity will have a strong influence in moving this zone upward or downward, according to regional conditions. This zone is limited by the point at which effective temperature ceases. Below this point is the *zone of activity.* In this zone will be found the degree of effective temperature, a long continuance of which is necessary to draw the insects out of hibernation. This is not an absolutely fixed point, for it varies with humidity.[1] Possibly the relation could be stated in a definite formula if a sufficient amount of data was available.

The temperature which causes activity is usually known as the *zero of effective temperature.* It is assumed that active metabolism begins at this point and that a certain amount of effective temperatures accumulated in daily units is necessary to bring about a given transformation or function. This sum is known as the *total effective temperature* for any given function. It will vary in accordance with the humidity. Below the zero of effective temperature there will be no necessity of feeding, and locomotion rapidly becomes impossible. On the approach of the zero of effective temperature the insects will display considerable activity in finding winter quarters. We therefore designate the zone below this zero as the *zone of hibernation.* The lower limit of this zone is the highest temperature which may be fatal under certain conditions of humidity or rapid alternation of temperatures. Below this point occurs a more or less restricted *lower zone of fatal temperatures.* The lowest point at which life can exist is known as the *minimum fatal temperature.*

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[1] Of course the manifestation of the absolute temperature which draws the weevils out of hibernation is dependent upon the density of shelter. Certain forms of shelter prevent the weevils from being affected until long after the outside air has been sufficiently warm to cause activity.

These zones are illustrated in the accompanying diagram (fig. 26).

UPPER ZONE OF FATAL TEMPERATURE.

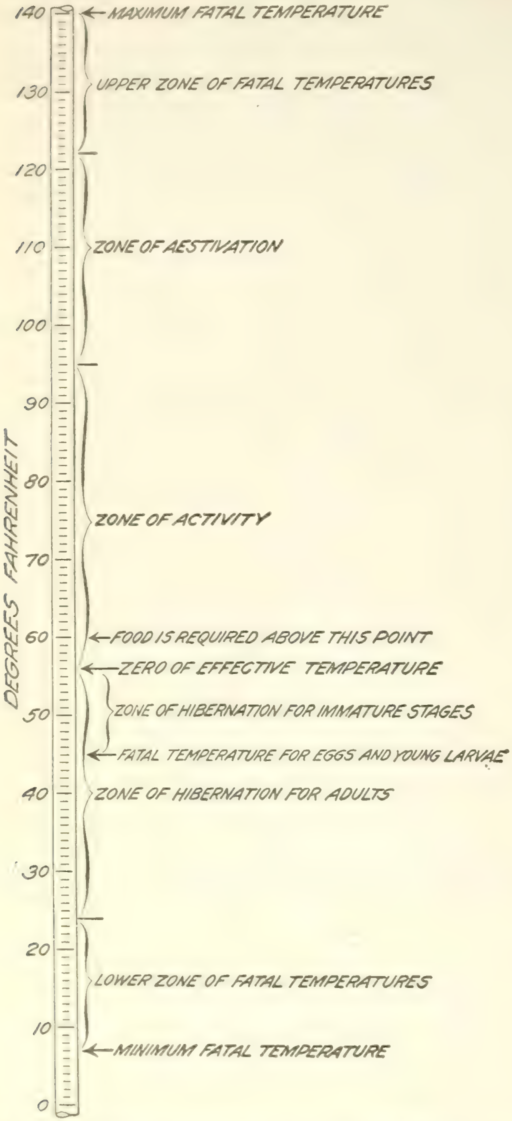
140
MAXIMUM FATAL TEMPERATURE
UPPER ZONE OF FATAL TEMPERATURES
130
120
110
ZONE OF AESTIVATION
100
90
DEGREES FAHRENHEIT
80
ZONE OF ACTIVITY
70
60
FOOD IS REQUIRED ABOVE THIS POINT
ZERO OF EFFECTIVE TEMPERATURE
ZONE OF HIBERNATION FOR IMMATURE STAGES
50
FATAL TEMPERATURE FOR EGGS AND YOUNG LARVAE
40
ZONE OF HIBERNATION FOR ADULTS
30
20
LOWER ZONE OF FATAL TEMPERATURES
10
MINIMUM FATAL TEMPERATURE
0

FIG. 26.—Diagram to illustrate the zones of temperature in their relations to the activities of the boll weevil. (Original.)

Numerous experiments have been conducted in dropping adult boll weevils upon the soil at different temperatures to determine the effects upon the insect. In this work 119 tests were made at soil temperatures varying from 110° to 140° F. Below 122° F. none of the weevils were killed, but from 122° F. upward death resulted in times varying from 1 second to 900 seconds. In a general way the exposure necessary to cause death decreased as the temperatures became higher. From these experiments we conclude that the upper zone of fatal temperature for the adult boll weevil may be considered as from 122° to 140° F.

In the series of experiments to which reference has been made a number of observations were made upon humidity. The atmospheric humidity during the time the experiments were under way, however, was rather constant, ranging from 37 per cent to 40 per cent. Within this narrow range it was not determined that humidity either decreased or increased the length of time necessary to cause the death at any fixed temperature.

It is interesting to note that the zone of fatal temperature for adult weevils which fall to the ground will be reached under general conditions when the temperature recorded at the usual distance above ground at which thermometers are placed reaches 95° F.

ZONE OF ÆSTIVATION.

During 1906 and 1907, in southern Texas, Mr. J. D. Mitchell observed that many adult weevils were on the ground near the cotton stalks under clods of earth and dead leaves, seeking protection from the intense heat. This indicates a distinct zone of æstivation, although such temperatures may exist only for a few hours at a time. The exact limitations of this zone are undeterminable. Æstivation is a very common habit among weevils. As throwing some light on the probable action of the boll weevil under high temperatures, it is of interest to state that Prof. C. H. T. Townsend, of Piura, Peru, finds that the Peruvian cotton square borer, *Anthonomus vestitus* Boheman, æstivates during the hot months in the fallen squares both as pupa and adult, but remains practically inactive.

ZONE OF ACTIVITY.

The temperatures at which most of the functions of the boll weevil are exercised lie between the means of 91° F. and 56° F. It is probable, however, that this zone approaches very close to the zone of fatal temperatures. In the spring effective temperature[1] begins to accumulate at approximately 56 degrees, but the total necessary to bring the weevils out of hibernation may be low if the rainfall and humidity for the same period are high, and it must be correspondingly high if the humidity is low.[2] When the two factors have accumulated enough between them they bring about emergence. It is roughly calculated that 172° of effective temperature and 5.1 inches of rain are necessary. A deficiency of effective temperature must be balanced by additional rainfall; a deficiency of rainfall must be balanced by additional effective temperature. For a fuller discussion of this subject see the section on emergence from hibernation (p. 107).

When the weevils have emerged and found food they require a certain number of days of feeding before oviposition can take place. This preoviposition period for hibernating weevils and for the succeeding generations is determined largely by temperature and humidity. As these two factors decrease the period increases. In like manner we have shown on preceding pages how the egg and larval and pupal stages are governed by the same laws. We have also shown that even the daily rate of oviposition is accelerated by increases in temperature and probably also of humidity.

The common impression that "rain brings the weevils" has its basis in the natural increase in the numbers of weevils shortly after a rainy period, due somewhat to the fact that increased humidity reduces the developmental period. A more important factor, however, is that humidity reduces the effects of sunshine in killing the weevil stages.

ZONE OF HIBERNATION.

The behavior of the weevils in hibernation is fully discussed elsewhere. In ice-box experiments at 45° F. it was found that the weevils would not emerge, but Dr. W. E. Hinds found that 10 weevils which had emerged from hibernation and which were confined 303 weevil days at 44° to 45° F. made 36 feeding punctures, or at the rate of one puncture every 8.4 days. It is probable that these punctures were all made possible by the removals from refrigeration for examination.

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[1] That is, the temperature at which activity begins.

[2] In a former publication (Bull. No. 51) we adopted the assumption made by other writers that 43° F. is the general zero of effective temperature for insects. Recent experiments have shown conclusively that this is an error, so far as the boll weevil is concerned.

LOWER ZONE OF FATAL TEMPERATURES.

In 1904 Dr. W. E. Hinds conducted experiments in the effects of low temperature on eggs and young larvæ. He found that 34 eggs at 45° F. for 13 to 14 days did not hatch when kept later at a temperature of 69° to 70° F. Recently hatched larvæ, however, were killed by nine days' exposure to 45° F.

By experiments conducted with adults in 1905 it was ascertained that 32° F. was not fatal; 24° F. benumbed the weevils, but they could revive; 18° F. killed.

In experiments conducted by Mr. H. P. Wood 32 weevils were exposed to a minimum of 15° F. and an average temperature of 18.6° F. for seven and one-fourth hours and then placed in the refrigerator at a higher temperature, but none recovered.

In similar experiments Mr. W. A. Hooker exposed 11 weevils for six hours to temperatures varying from 15° to 20° F. The weevils were quiet, but later showed signs of life, although they died within two days. Between 7 and 10 degrees, five weevils were killed in six hours. One degree below zero was absolutely fatal.

Observations on the effects of low temperatures upon the weevils in the fields leads to the statement that all places experiencing a temperature under 12° F. in the early part of the winter will profit by an almost complete extinction of the weevil, depending somewhat, of course, upon the amount of protection the weevils may have secured before the freeze. Regions having a normal minimum temperature of zero need have little fear of serious continued depredations from the weevil until the insect has proved itself able to adapt itself to colder temperatures than it is now able to withstand.

In this connection it will be of interest to submit Table LXI, giving the average winter mortality from cold since the beginning of our records.

TABLE LXI.—*Weighted average cold control of immature stages of the boll weevil, by months.*

Month.	Forms examined.	Stages found.	Killed by cold and wetting.
			Per cent.
January	5,687	1,285	36.42
February	13,597	665	67.36
March	2,500	159	31.44
November	2,534	798	41.40
December	2,663	688	38.37
Total	26,981	3,595	44.61

It should be noticed that winter cold is, on the average, almost twice as effective as summer heat.

The history of the boll weevil furnishes several examples of winter control, principal among which are the early freezes of November, 1907, November, 1908, and December, 1909, which greatly reduced weevil damage in large sections.

FATAL VARIATIONS OF TEMPERATURE.

It has long been known that one of the most potent forces in insect control is abnormal variation of temperature. Probably no stronger illustration of such control could be produced than that afforded by the conditions of the winter of 1910–11.

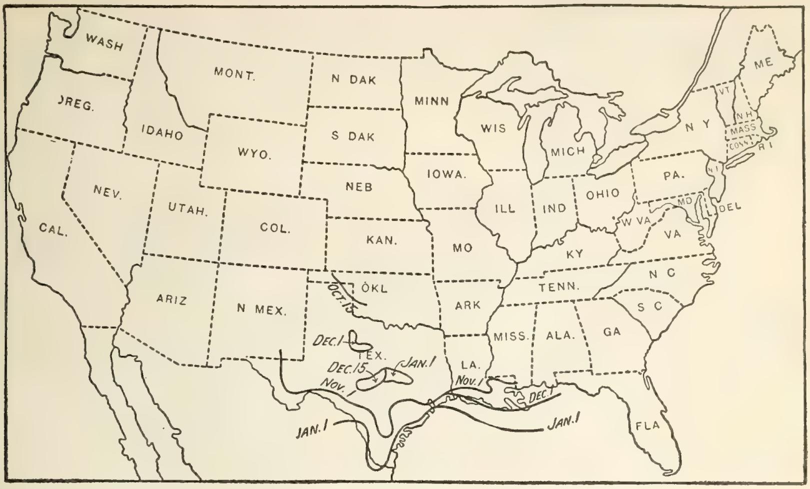
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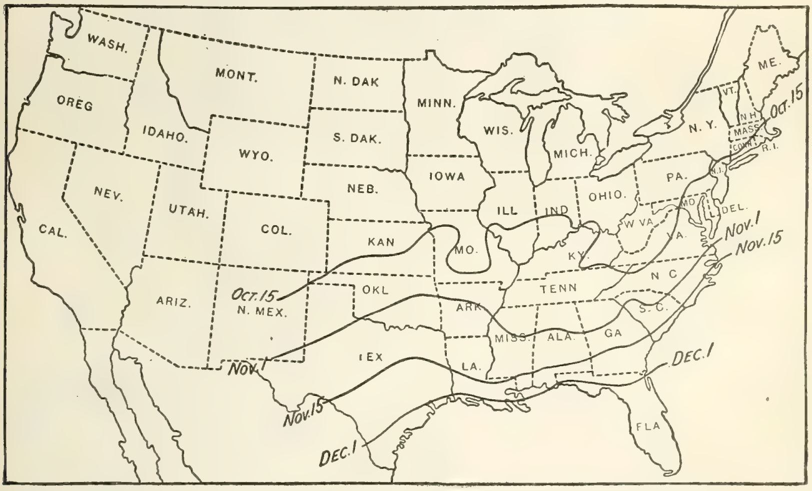
FIG. 27.—Map showing dates of first killing frost in the area infested by the boll weevil, in the winter of 1909–10. (Original.)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Dec.1

FIG. 28.—Map showing normal dates of first killing frost in the southern United States. (After Weather Bureau Bulletin V.)

On October 29 to 30, 1910, a freeze occurred throughout the cotton belt affecting all but a narrow strip of territory along the Gulf coast and two small interior areas of Texas, as illustrated by the accompanying map (fig. 27). Another map (fig. 28) is presented to show the normal dates of the first killing frosts. Comparison of these two maps will show at a glance that the first killing freeze of 1910 was over a month earlier than the normal. Such a natural phenomenon is an exact equivalent of artificial fall destruction at the same date. The temperatures were not fatal to the weevils, but were such as to force hibernation and at the same time cut off food supply. If temperatures compelling hibernation had continued, the weevils would have emergep in about the same proportion as would be expected if they were artificially deprived of food on the same date. However, another climatic factor intervened. Almost the entire month of November was warm, and throughout Louisiana, at least, the mean temperature stood at above 56° F. for the month. We have already shown that a continuance of mean temperatures over 56° F. will force the weevils to take food, and that in the absence of food at effective temperatures starvation occurs in a few days. If all of the cotton had been killed by the freeze, the control would have been complete, but there are always sheltered areas on hillsides or near buildings that escape two or three severe freezes, and these areas no doubt harbored many weevils until the cold wave of November 29 drove them to a normal hibernation.

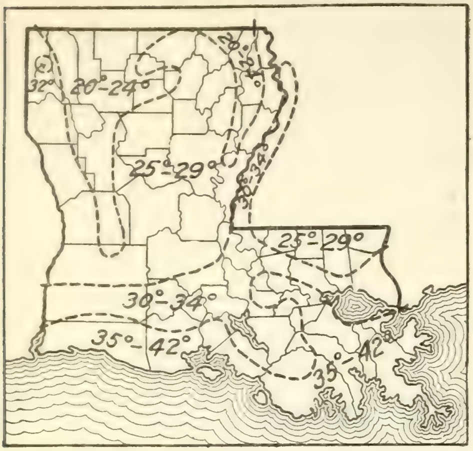

Fig. 29.—Map showing minimum temperatures on October 29 and 30, 1910, the date of the first killing frost in Louisiana. (Original.)

In the map (fig. 29) showing the Louisiana minimum temperatures of October 29 and 30, 1910, on which dates the first killing frost occurred, it will be noticed that no fatal temperature was reached, but that a freezing temperature occurred in practically all of the cotton-producing territory. The other map (fig. 30) illustrates the minimum temperatures of the entire winter of 1910–11 and shows that fatal temperatures (7° F. to 22° F.) occurred throughout the State. These minima

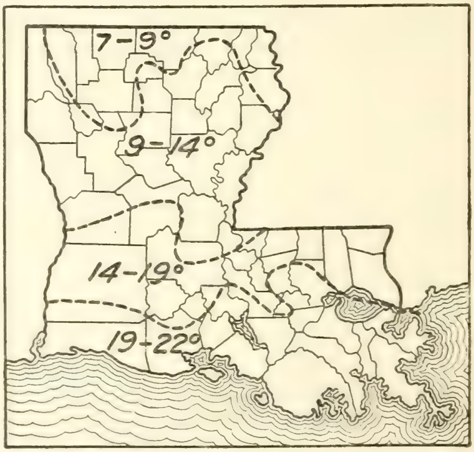

Fig. 30.—Map showing minimum temperatures in the winter of 1910–11 in Louisiana. (Original.)

occurred, however, early in January, at which time all weevils which had survived the starvation of the fall were deeply hidden in hibernation shelters, where sudden changes of temperature have little effect.

The survival from hibernation at Tallulah, La., was only one-half of 1 per cent, as shown in the hibernation statistics, and this, no doubt, must be attributed to the rare combination of early freeze, subsequent long duration of effective temperatures without food, and finally a period of minimum fatal temperatures.

One of the most interesting features of the fall of 1910 in Texas was the presence of two small areas in which the first freeze was delayed from one to two months. (Fig. 27.) We call attention to the most interesting of these cases. The freeze of October 29 was felt in all Texas above the latitude of 31°, except in Erath, part of Comanche, part of Brown, Eastland, Callahan, Taylor, Jones, and Haskell Counties in central-west Texas. In this frost-free area in the following October, 1911, a very heavy infestation was found at Cisco, in Eastland County, and at Brownwood, in Brown County. The infestation diminished in every direction from those places. At Lampasas, 60 miles southeast of Brownwood, where we would naturally expect a much higher infestation than at Cisco, very slight damage occurred, and at Granbury, in Hood County, 60 miles east of Cisco, where the weevils have been present since 1904, they were extremely difficult to find. Thus, it is seen that a territory which had had the weevil much longer than either Brownwood or Cisco had fewer weevils in 1911, because it experienced an earlier killing frost.

EFFECTS OF FLOODING UPON THE WEEVIL.

Tests at Victoria, Tex., in 1904, were divided into two parts, each of which included both the immature and mature stages. In each part floating and submergence were tested. In the tests made upon the floating power of adults, weevils were isolated and placed in water in tumblers. They were dropped from a considerable distance above the surface, so that they became entirely submerged, and they rose to the surface naturally. The surface tension of the water was found to be sufficient to float weevils which were placed upon it carefully. The generally hairy condition of the surface of the weevil's body prevents it from being readily wetted, so that it may struggle for some time in the water without becoming really wet. When dropped, as described above, weevils float head downward, with the tip of the abdomen above the surface. In the submergence tests weevils were held down by a wire screen, and all bubbles were removed from their bodies by a pipette, thus making the tests as severe as possible.

Sixty squares believed from external examination to be infested were floated in a driving rain for six hours. They were then removed and left for several days, during which time 75 per cent of them produced normal adults. Ten squares which were floated in driving rain for six hours were opened at once, and in every case found to be only slightly moist on the inside. These contained six larvæ and four pupæ, and all were in perfect condition.

As squares float normally, submergence tests were considered extreme. Five squares were submerged for six hours, and after that produced three normal adults; one pupa died, and one square was found to have been uninfested. Five more squares were submerged for 31 hours. These produced two normal adults, and one pupa died in the process of molting after removal from the square. Death was probably caused in the last case by drying; one square was found to contain a dead pupa, and one was not infested. To test the possibility of its living, should the square be penetrated by water, a naked pupa was submerged for six hours, but in spite of this unusual treatment it produced a normal adult. Numerous larvæ removed from squares and placed in water pupated in one or two days, and several pupæ remained alive, though floating for several days in water before they transformed into adults.

In the case of squares floating normally it is evident that they might remain in water for several days without injury to the weevil within. Very slight wetting of the cell takes place, even under the extreme conditions of submergence. The effect of a brief flood would not, therefore, be at all injurious. As adults float as readily as do squares, they may also be carried long distances, and, furthermore, they are able to crawl out of the water upon any bushes, weeds, or rubbish which they touch. Even when floating for several days continuously they are able to live and may be carried directly to new fields. The floating of adults and infested squares explains the appearance of weevils in great numbers along high-water lines immediately after a flood.

Field observations were made to supplement the laboratory experiments recorded in the preceding paragraphs. In July, 1904, many fields in the vicinity of Victoria, Tex., were partially and some wholly submerged. This condition lasted for several days. Examination made after the recession of the water showed that many fallen squares which had been in the water for some time contained uninjured larvæ and pupæ. Naturally, eggs and larvæ found in squares upon the plants, even though under water for some time, escaped unharmed. Weevils were working normally upon the plants. No diminution in their numbers could be seen, and it was apparent that the overflow caused no check either to the development of the immature stages or to the activity of the adults.

PLANT CONTROL.

While climate is the foremost factor in the control of the boll weevil and also of the behavior of the cotton plant, there are certain kinds of control which the plant itself exerts. One of the most important of these is proliferation, which will be discussed in the following paragraphs.

PROLIFERATION.

Early in the investigation of the boll weevil it was noticed that the immature stages and sometimes even the adults are frequently killed by a form of reaction of the plant known as proliferation.[1] It appears that this property of the plant might be emphasized by breeders. For this reason special studies were conducted in 1905 and 1906. The results were published in Bulletin 59 of the Bureau of Entomology from which the following statements are abstracted.

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[1] Dr. O. F. Cook, of the Bureau of Plant Industry, has published a number of papers in which references are made to proliferation. The reader is referred to these papers, which are included in the bibliography at the end of this bulletin, for a full discussion of the botanical aspects of the phenomenon.

For the present purposes proliferation may be defined as the development of numerous cells from the parts of the bud or boll of the cotton plant which are injured by the weevil. It is clearly a manifestation of an inherent tendency on the part of the plant to counteract irritation by the growth of large numbers of new cells. This growth usually begins in the layer of cells adjoining the lining of the boll or in the staminal column of the undeveloped bloom. Part of the formation may project through the rupture made by the weevil or may form a hemispherical mass protruding from the inner side of the carpel of the boll and pressing into the lock. The reaction on the part of the plant begins generally before the egg hatches. In some cases the egg itself may be moved a considerable distance by the growth. In other instances the egg becomes enveloped and the larva emerges in the proliferous mass. Under such circumstances it may be destroyed early in life, although it often makes its way through the mass into portions of the fruit which have not been affected. As the larva feeds it continues and increases the irritation, and the response of the plant is immediate. In this way it often happens that the space the larva has eaten out becomes filled by the proliferous mass, and the pressure becomes so strong that eventually the larva or the resulting pupa or adult is crushed. It is clear from the observations made that it is this crushing effect that destroys the weevil. (See Pl. XIV, *b*.) A number of experiments in which weevil larvæ were placed in proliferous tissues showed that they could develop normally upon this modification of their natural food.

The frequency of the occurrence of proliferation was determined by the examination of 1,870 squares and 2,042 bolls of a large number of American and several foreign cottons. In the case of squares, it was found that in the averages for all seasons and localities proliferous growth followed feeding punctures in 48 per cent of the cases. The highest percentage, 75, was in the case of the Jannovitch, an Egyptian variety. In the case of bolls, proliferation followed in 81 per cent of the cases of feeding punctures. It is consequently apparent that proliferation occurs more frequently as a result of feeding punctures in bolls than in the case of punctures in squares.

No very satisfactory results followed a study of the effect of climatic conditions upon the frequency with which proliferation follows the attack of the weevil. The observations included a number of varieties growing in two localities during two seasons, but there seems to be no special relation between the locality and the season and the number of cases in which proliferation was found. In fact, the maximum percentage of formation of proliferation in bolls and the minimum in squares occurred at the same time in the same locality and with the same variety.

Table LXII shows the weevil mortality due to proliferation in squares and bolls under natural conditions.

Table LXII.—*Summary of observations showing increased mortality of the boll weevil in squares and bolls caused by proliferation.*[1]

Years of observation.	Localities covered.	Varieties included.	Squares examined.			Mortality in squares.		Increase in mortality due to proliferation.	Bolls examined.	Locks examined.			Mortality in locks.		Inhrease in mortality due to proliferation.
			Total number.	Number with proliferation.	Per cent with proliferation.	With proliferation.	Without proliferation.			Total number.	Number with proliferation.	Per cent with proliferation.	With proliferation.	Without proliferation.	
						P.ct.	*P.ct.*	*P.ct.*					*P.ct.*	*P.ct.*	*P.ct.*
1902	4	4	105	44	41.9	30.5	19.5	11.0							
1903	1	1							246	1,033	434	42.0	15.0	5.0	10.0
1903	1	1							452	1,898	995	52.4	28.4	12.8	15.6
1904	1	9	2,954	1,480	50.0	9.6	.6	9.0							
1904	2	2							398	1,708	885	51.8	18.2	11.1	7.1
1905	1	14	4,504	2,365	52.5	19.6	5.5	14.1							
1905	1	6	771	372	48.2	28.6	.3	28.3							
1905	1	1	443	212	47.9	25.1	9.7	15.4							
1905	1	4	144	40	27.8	34.8	3.2	31.6							
1905	1	14							1,802	7,821	5,069	64.8	16.7	8.5	8.2
1905	1	1							82	254	158	62.2	14.6	.0	14.6
Totals and averages			8,921	4,513	[2]50.6	[2]17.2	[2]3.7	[2]13.5	2,980	12,714	7,541	[2]59.3	[2]15.5	[2]9.2	[2]6.3

[1] From Bulletin 59. Bureau of Entomology, p. 27.

[2] Weighted average.

It will be seen that in the case of squares there was a range of from 9 to 31 per cent increase in the mortality due to proliferation, the general average being 13 per cent. In bolls the range is not so great, being only from 7 to 15 per cent, while the average increase in mortality in bolls was found to be 6 per cent. This is slightly less than one-half as great a mortality as was found to be the case in squares.

A number of interesting experiments were performed to determine whether artificial punctures were as frequently followed by proliferation as those made by the weevil. One thousand one hundred and three needle punctures were made, resulting in proliferation in 36 per cent of the cases. This percentage is not so large as in the case of feeding punctures of the weevil, but it is as large as could be expected when the difference between a clean needle puncture and the rough, lacerating puncture by the weevil is considered. It consequently appears that it is the mechanical injury of the weevil rather than any secretion which causes the growth. A further series of experiments showed that injections of caustic potash, formic acid, and other chemicals did not appear to increase the number of cases in which proliferation followed. It did appear, however, that unsealed artificial punctures resulted in more frequent proliferations than sealed punctures of the same kind.

A number of experiments were instituted to show the possible effect of heavy fertilization of the cotton plant upon its tendency to form proliferous tissues. It was supposed that some such cultural expedient as fertilization might increase the resistance on the part of the plant. In the case of over 8,000 observations made on fertilized cotton growing in two localities, however, it was found that proliferation followed attack by the weevil practically as frequently in the one case as in the other. Squares on fertilized plats showed proliferation in 50.5 per cent of the cases; on unfertilized plats in 49.5 per cent. Bolls on fertilized plats showed proliferation in 66.2 per cent of the infested locks; on unfertilized plats in 69.5 per cent.

It was found that proliferation very frequently follows the attacks of any of the insects which injure the cotton boll or square. In the case of these other insects the phenomenon is of little importance, since, unlike the weevil, they generally make punctures merely for the purpose of feeding. The immature stages are not developed in the cotton fruit and are consequently beyond the reach of the growth which the adults have incited.

OTHER PHASES OF PLANT CONTROL.

There are other forms of plant control which require attention. Dr. O. F. Cook, of the Bureau of Plant Industry, has been the principal student of this matter and has called attention to numerous weevil-resisting adaptations of the cotton plant, although important contributions have been made by several other investigators. Among the more important properties or tendencies of the cotton plant which affect the weevil adversely are: (1) Early bearing, (2) determinate growth, (3) hairy stalks and stems (Pl. XIV, *a*), (4) abundance of secretion from nectaries, (5) pendent bolls, (6) involucral bracts grown together at base, (7) thick-walled bolls, and (8) tendency to retain infested fruit (Pl. XV).

Early bearing enables the plant to produce its fruit before the weevils have become numerous. In other words, it allows the plant to take advantage of the small number of weevils which succeed in passing the winter and also to take advantage of the comparatively slow development of the insect during the early portion of the growing season.

Determinate growth prevents the maturity of numerous weevils in the fall. Plants with this character well marked discontinue both growth and fruiting. As the capacity of the weevil to increase is limited very largely by the amount of fruit available, it is evident that a variety which discontinues fruiting at an early date in the fall must reduce greatly the number of weevils that are present to go into winter quarters.

It has been found that the presence of a considerable growth of hair on the stalks and stems presents an important obstacle to the progress of the weevil and consequently reduces the daily capacity of damage of each insect. In some of the American upland varieties, notably the King, this hairiness is developed to such an extent as to be a form of protection of considerable importance.

As has been pointed out in another section of this bulletin, boll-weevil parasites in the adult stage feed upon the nectar which is secreted by the cotton plant. Consequently the greater the secretion of nectar the more favorable will be the conditions for these important enemies of the weevil.

There is a more or less constant tendency on the part of the adult weevil to frequent the upper portion of the cotton plant. If it happens to alight upon a lateral branch which has bolls or squares standing upright, attack follows immediately. On the other hand, if the branch upon which the weevil alights has bolls which turn downward, there is a considerable likelihood that it will work upward to other lateral branches and overlook the fruit upon the first branch.

The weevil has frequently been observed to experience considerable difficulty in reaching the cotton square through the involucral bracts. If these bracts are united at the base, or very closely appressed, or have their edges provided with strong hairs, the natural difficulty the weevil experiences will be increased.

Dr. Cook has pointed out that certain Central American strains of cotton have bolls provided with thick interior walls, which in some cases the weevil is unable to penetrate.

As has been pointed out in another section, the insect enemies of the boll weevil find the infested squares which remain on the plants more suitable for attack, and are able to raise the average control above that in fallen squares in most sections. Consequently it is of advantage to the planter to have a variety with a well-marked tendency to retain the infested fruit. The ability to retain the infested squares is explained under the heading of parasite attack (p. 144).

Several other peculiarities of the cotton plant which Dr. Cook has interpreted as weevil-resisting adaptations are described in Bulletin 88 of the Bureau of Plant Industry of this department.

DISEASES.

Little attention has been given to the study of diseases of the boll weevil because the observations upon the mortality of the insect have not indicated any great amount of death due to causes which could not be well explained under the headings of climatic, plant, parasitic, and predatory control. There is no doubt that bacterial and fungous diseases sometimes attack the weevils, especially those hibernating in moist places. Only two definite records are at hand of death by fungus, and these have been recorded in former bulletins. One was a case of a new species of Aspergillus and the other of a species of Cordyceps.

PARASITIC AND PREDATORY INSECT ENEMIES.

Recent work has added very greatly to our knowledge of the insect enemies of the boll weevil. Much remains to be done, however, since it has been found that the boll weevil is accumulating species after species of parasites as it advances farther into the United States. A recent publication of this bureau (Bulletin No. 100) has dealt rather extensively with the insect enemies of the boll weevil. In the present publication, therefore, only a few of the more important facts learned will be considered.

A BRIEF SUMMARY OF THE INSECT SPECIES ATTACKING THE BOLL WEEVIL.

At the present time the boll weevil is known to be the host of 29 species of parasites, of which 4 are mites, 21 belong to the order Hymenoptera, and 5 are parasitic flies. In addition to these true parasites, there are 6 predators which kill the adult boll weevils and 22 predators which attack the immature stages. These include a mantis, a predatory bug, 8 beetles, a leaf-feeding caterpillar, and 17 species of ants. In all, the boll weevil is known to have 58 species

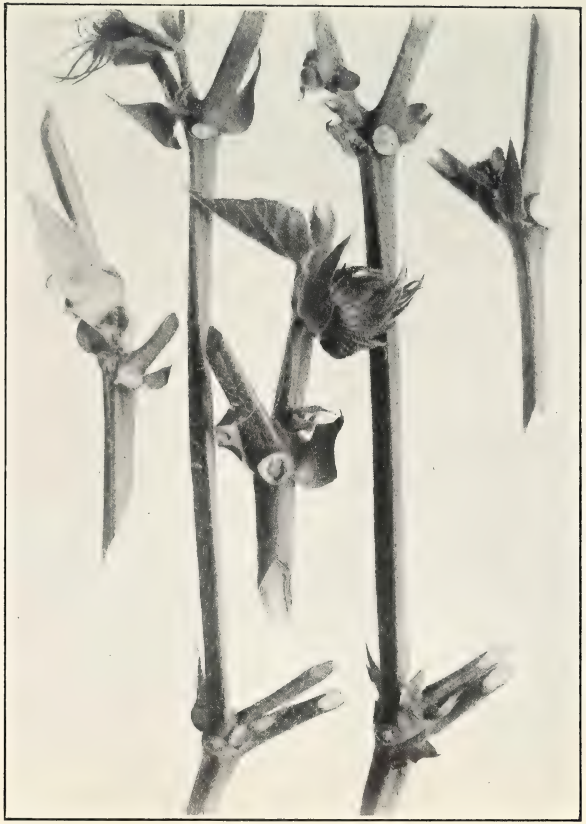

Fig. a.—Cotton squares with short abscis layer, permitting infested squares to fall. (Original.)

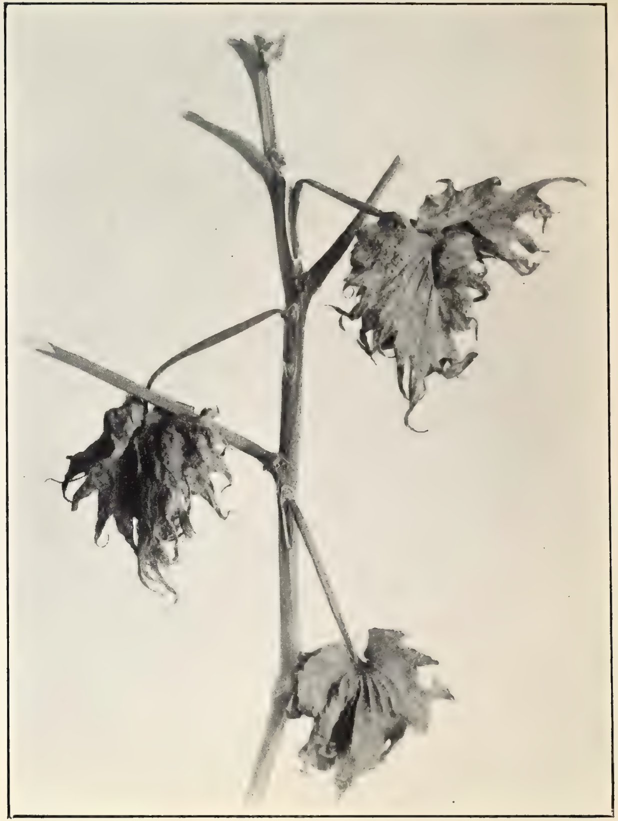

Fig. b.—Cotton squares with long abscis layer, retaining infested forms to hang and dry. (Original.)

THE DIFFERENCE BETWEEN HANGING AND FALLEN SQUARES.

of insect enemies, and probably many more species will be found as the weevil enters new regions. In fact, records of parasite and ant attack have been found as early as two weeks after invasion of new territory.

ARACHNIDA. ACARINA. SARCOPTOIDEA.

Pediculoides ventricosus Newport.—This mite has been prominent in the study of the boll weevil since its first notice (Rangel, 1901) under the name of *Pediculoides ventriculosus*. These mites reproduce viviparously, and their offspring are mature and fertile at birth. After attachment to a host the abdomen begins to inflate until it becomes many times greater than the thorax. The time required for engorgement varies from two to five days. An average of 100 female offspring to an individual has been recorded.

Pediculoides n. sp.—This mite was discovered in the laboratory at Dallas, Tex., June 13, 1907, by the junior writer. Observations continued for some time proved that there was a generation about every four days. The mite has been found attacking several other species of weevils as well as many other insects.

Tyroglyphus breviceps Banks.—This species has been recorded as an enemy of the boll weevil from Victoria, Tex. A similar mite has also been found at Calvert, Tex.

GAMASOIDEA.

Macrocheles n. sp.—Mr. Harry Pinkus found this mite very common in the fallen cotton squares at Tullulah, La., during August, 1911, feeding upon the boll-weevil stages. It has not been definitely proved that the species kills the weevil, but the evidence is more or less conclusive.

INSECTA. ORTHOPTERA. MANTIDÆ.

Stagmomantis limbata Hahn.—This insect has been found to prey upon the adult boll weevil in Texas.

HETEROPTERA. REDUVIIDÆ.

Apiomerus spissipes Say.—This predatory bug has been recorded by Mr. A. C. Morgan as an enemy of the adult boll weevil in Texas.

COLEOPTERA. CARABIDÆ.

Evarthrus sodalis Le Conte.—This species (fig. 31) is a predator upon the adult boll weevil in Louisiana and Texas.

Evarthrus sp.—Another species of the genus has been recorded by Newell and Trehearne as predatory upon adult boll weevils at Baton Rouge, La.

CANTHARIDÆ.

Chauliognathus spp. (see fig. 32).—The larvæ of these beetles are very common in the squares and bolls of cotton in Louisiana and Mississippi. In one instance undoubted proof of the attack of such a larva upon a boll-weevil larva was recorded.

CLERIDÆ.

Hydnocera pallipennis Say.—A single beetle of this species was reared April 6, 1907, from the boll weevil, collected August 28, 1906, at Waco, Tex.

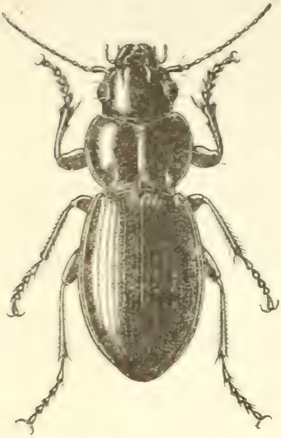

FIG. 31.—*Evarthrus sodalis*, an enemy of the boll weevil. (Original.)

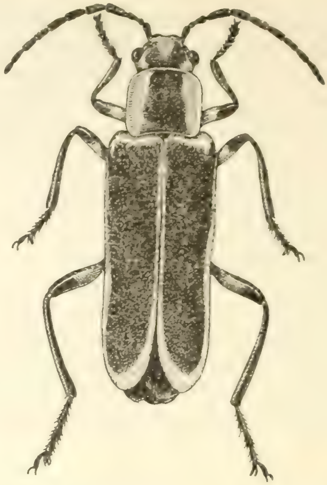

FIG. 32.—*Chauliognathus marginatus*, an enemy of the boll weevil. (Original.)

Hydnocera pubescens Le Conte (fig. 33).—This is a very common breeder in the weevil cells. Its larvæ have been not only found feeding upon the various weevil stages, but have been frequently observed feeding upon the parasites of the weevil.

CUCUJIDÆ.

Cathartus gemellatus Duval.—This beetle is a predator and scavenger, its larvæ being frequently found feeding upon boll-weevil stages which they must have killed.

TENEBRIONIDÆ.

Opatrinus notus Say.—This beetle has been found by Mr. Harry Pinkus at Tallulah, La., to prey as an adult upon the immature stages of the weevil in fallen squares during July. It occurred very commonly in the cotton fields.

LEPIDOPTERA. NOCTUIDÆ.

Alabama argillacea Hübner.—For many years the ravages of the cotton leaf worm attracted almost as much attention in some portions of the South as does the damage by the boll weevil now. Various changes in the system of cultivation of cotton in the South have combined to reduce the damage done by this pest, and, moreover, a very effective method of controlling it, by the use of Paris green, was discovered. It is one of the striking occurrences in the history of economic entomology that this formerly dreaded pest is now looked upon by the farmers in weevil-infested regions as decidedly beneficial.

When the plants become defoliated by the leaf worms the growth is checked, and consequently the opportunities for the breeding of the weevils in additional squares are reduced. This results in a marked decrease in the number of weevils at the end of the season. This decrease has not so much effect upon the crop of the current year as upon the following one by reason of the lessened number of weevils that pass through hibernation. Moreover, when the plants have been deprived of most of their leaves the worms very frequently devour the squares and sometimes small bolls in which the immature stages of the boll weevil are located. In this way the leaf worm acts directly as a remedial agency against the boll weevil. This work to some extent accomplishes the same result as the fall destruction of the plants, which, as is well known, is the greatest single factor in the successful production of cotton in weevil-infested regions. There is still another consideration in this connection, namely, that the defoliation of the plants allows the sun to strike the squares upon the ground, thus destroying many of the larvæ and pupæ of the weevil contained therein. At the present time, as the result of the conditions mentioned, the planters in the infested regions are rapidly giving up the practice of poisoning the formerly much dreaded caterpillar. If, as may occasionally happen, the plants become defoliated before the weevils reach the maximum numbers in the fields, the damage of the one insect will simply be added to the damage of the other. In that event the use of poison will be necessary.[1]

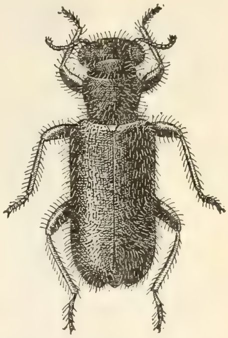
FIG. 33.—*Hydnocera pubescens*, an enemy of the boll weevil. (Original.)

In the extensive defoliation by the leaf worm in 1911 one of the most striking features was the scattering of the boll weevil for great distances into new territory. The general absence of green fields caused the weevils to fly much farther than they would otherwise have done.

HYMENOPTERA. FORMICOIDEA. DORYLIDÆ.

Eciton (*Acamatus*) *commutatus* Emery (Pl. XVI, *a*).—This ant has been observed only once, at Beeville, Tex., attacking the weevil larvæ in squares.

PONERIDÆ.

Ectatomma tuberculatum Olivier.—The "kelep," or so-called Guatemalan ant, is a native of Mexico and Central America. Like all other ponerids, it is slow in action, but is able to capture such weevils as come within its reach on the cotton plants. Numerous attempts to establish this species in the United States have failed.

MYRMICIDÆ.

Cremastogaster lineolata Say, subsp. *læviuscula* Mayr, var. *clara* Mayr. (Pl. XVI, *b*).—This ant, although normally a honeydew feeding species, is also an enemy of the immature stages of the boll weevil in Texas.

Solenopsis geminata Fabricius, var. *diabola* Wheeler.—The common fire ant of the Southern States is one of the best enemies of the boll weevil, being very industrious in its search for infested squares, which it enters in great numbers.

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[1] The above paragraph is from W. D. Hunter in the Yearbook of the Department of Agriculture for 1904, p. 201.

Solenopsis molesta Say (Pl. XVI, *e*).—This minute ant was taken in the act of attacking a boll-weevil larva at McAlester, Okla., by Mr. R. A. Cushman.

Solenopsis texana Emery.—This ant is a common enemy of the immature stages of the boll weevil in Texas, Louisiana, and Mississippi.

Monomorium minimum Buckley.—The common house ant is a very valuable enemy of the boll weevil in Texas, Louisiana, and Mississippi.

Monomorium pharaonis Linnæus (Pl. XVI, *d*).—This cosmopolitan house ant is another of the more important boll-weevil enemies in Texas, Louisiana, and Arkansas.

Pheidole sp. near *flavens*.—This species was found abundantly attacking the immature stages of the boll weevil at Arlington, Tex., August 31, 1908, by Mr. R. A. Cushman.

Pheidole crassicornis Emery.—This species was found as an abundant enemy of the immature stages of the weevil at Lampasas, Tex., September 23, 1908, by Mr. R. A. Cushman.

DOLICHODERIDÆ.

Forelius maccooki Forel.—This ant has been recorded at several places in Texas as an enemy of the immature stages of the boll weevil.

Dorymyrmex pyramicus Roger (Pl. XVI, *c*).—The so-called lion ant of Cuba was recorded by Mr. E. A. Schwarz (1905) as protecting solitary tree cotton from the boll weevil.

Dorymyrmex pyramicus Roger, var. *flavus* Pergande.—This common cotton-field ant has only once been recorded definitely as an enemy of the boll weevil. This record is from Texarkana, Tex., by Mr. R. C. Howell.

Iridomyrmex analis Ern. André. (Pl. XVI, *f*).—This common ant is normally a honey-loving species, but occasionally attacks insect food. It has been found attacking the boll weevil by Dr. W. E. Hinds.

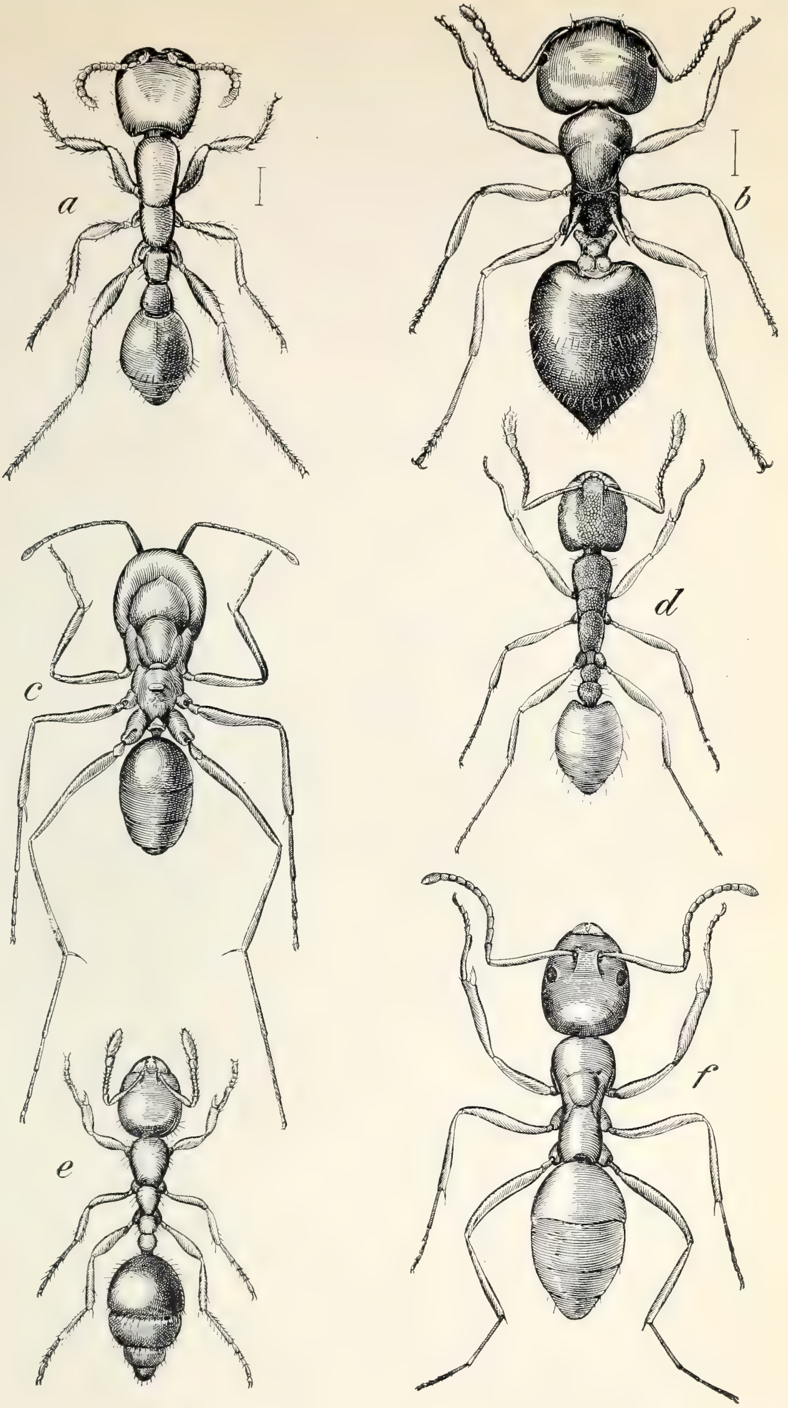
Iridomyrmex humilis Mayr.—The Argentine ant has formerly been recorded as an enemy of *Solenopsis geminata*, *Monomorium pharaonis*, and *Iridomyrmex analis*, three of our common boll-weevil enemies. Mr. T. C. Barber has recently reported that the Argentine ant, by continually worrying the boll weevils and killing newly emerged adults, practically cleared a heavily infested cotton patch at Baton Rouge, La., in September, 1909, at a time when fields outside of the ant territory were still very seriously infested.

FORMICIDÆ.

Formica subpolita Mayr, var. *perpilosa* Wheeler.—This species is normally a honey feeder, but has been recorded by Rangel (1901) as a predator upon adult weevils in Mexico.

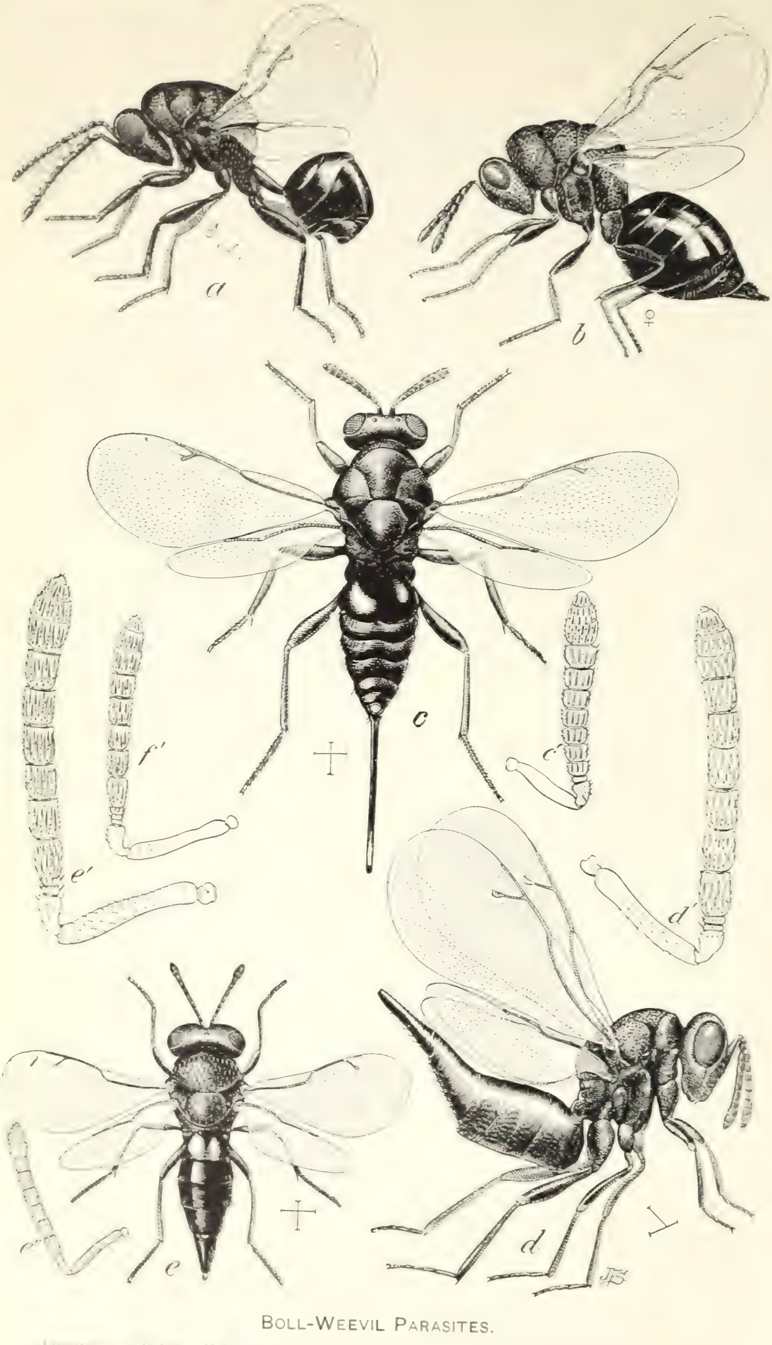
Formica pallidi-fulva Latreille.—A single instance of this species cutting its way into a boll weevil-infested square was observed by Mr. C. E. Hood at Ashdown, Ark., September 2, 1908. The species is commonly found on the cotton plants.

Prenolepis imparis Say.—Mr. C. E. Hood recorded this species as an enemy of the immature stages of the boll weevil at Ashdown, Ark., September 2, 1908.



BOLL-WEEVIL ANTS.

a, *Eciton commutatus*; *b*, *Cremastogaster lineolata*; *c*, *Dorymyrmex pyramicus*; *d*, *Monomorium pharaonis*; *e*, *Solenopsis molesta*; *f*, *Iridomyrmex analis*. (Original.)



BOLL-WEEVIL PARASITES.

a, Eurytoma tylodermatis, male; *b, Eurytoma tylodermatis*, female; *c, Microdontomerus anthonomi*, female; *c'*, antenna of same; *d, Habrocytus piercei*, female; *d'*, antenna of same; *e, Catolaccus hunteri*, female; *e'*, antenna of same; *f'*, antenna of *Catolaccus incertus*. (Original.)

HYMENOPTERA. CHALCIDOIDEA. CHALCIDIDÆ.

Spilochalcis sp.—A single male of this species was found dead in a weevil cell with the remains of the weevil and its own exuvium August 10, 1907, at Victoria, Tex.

TORYMIDÆ.

Microdontomerus anthonomi Crawford (Pl. XVII, *c*).—This is one of the most important parasites of the boll weevil in Texas and Louisiana. It is generally found throughout the year and is known to attack two other species of weevils.

EURYTOMIDÆ.

Eurytoma tylodermatis Ashmead (Pl. XVII, *a*, *b*).—This species ranks among the five most important boll-weevil parasites, and its range is practically coextensive with that of its host. It is known to attack 14 other species of weevils.

Eurytoma sp.—Two species of this genus were reared from hanging squares collected August 10, 1907, at Victoria, Tex.

Bruchophagus herreræ Ashmead.—This parasite has been recorded from the boll weevil from Mexico, but the name is thought to be a synonym of *Eurytoma tylodermatis*.

PERILAMPIDÆ.

Perilampus sp.—A single individual was reared from the boll weevil by isolation from material collected September 7, 1907, at Shreveport, La., by Mr. C. E. Hood. Considerable doubt has been raised concerning this record by authorities upon the breeding habits of Perilampidæ.

ENCYRTIDÆ.

Cerambycobius cyaniceps Ashmead (Pl. XVIII, *f*).—The range of this species is coextensive with the boll weevil in the United States. It is extremely important in northern Louisiana and Arkansas, and is known to attack 17 species of weevils.

Cerambycobius cushmani Crawford.—This species is evidently limited to southern Texas, where it is occasionally important. It is known as a parasite of four other species of weevils.

Cerambycobius sp.—On February 23, 1909, a male of a green species of this genus was reared from a weevil in squares collected at Natchez, Miss., on January 19.

PTEROMALIDÆ.

Catolaccus hunteri Crawford (Pl. XVII, *e*).—This is one of the most important parasites of the boll weevil. It is of greatest importance in Louisiana and Mississippi. Twelve other species of weevils are known as hosts.

Catolaccus incertus Ashmead (Pl. XVII, *f'*).—This is also a very important species and occurs throughout the infested region. It is also a parasite of 13 other species of weevils.

Habrocytus piercei Crawford (Pl. XVII, *d*).—This brilliant green parasite has been reared from the boll weevil only in the fall and winter months in Louisiana and Texas. One other weevil host is known.

Lariophagus texanus Crawford (Pl. XVIII, *a*).—There is strong evidence that this species is a primary parasite of the boll weevil in southern Texas. It is also undoubtedly a parasite of four other species of weevils.

EULOPHIDÆ.

Tetrastichus hunteri Crawford (Pl. XVIII, *b*, *c*).—This parasite of the boll weevil has been known only since 1908. It is the only internal hymenopterous parasite of the weevil and occurs commonly in Louisiana and Mississippi and has been recorded from Texas. It is evidently more important in the fall of the year.

ICHNEUMONIDEA. ICHNEUMONIDÆ.

Pimpla sp.—On February 23, 1909, a single female of this species was reared from a weevil larva collected at Nacogdoches, Tex., on January 27.

BRACONIDÆ.

Sigalphus curculionis Fitch.—This common parasite of the plum curculio has been found frequently attacking the boll weevil in Louisiana and Mississippi. It is known as a parasite of eight other species of weevils.

Urosigalphus anthonomi Crawford.—This species has been reared from the boll weevil only at Brownsville, Tex.

Urosigalphus schwarzi Crawford.—This species is a parasite of the boll weevil in Guatemala and has never been reared in the United States.

Urosigalphus sp.—A single specimen of this species was reared in 1909 at Arlington, Tex.

Microbracon mellitor Say.—Until 1909 this was the most important parasite of the boll weevil. It is coextensive in distribution with its host, but is by far most important in Texas and Oklahoma. It is known as a parasite of 10 other species of weevils.

An unknown braconid, nearly related to Glyptocolastes, was reared from the boll weevil in southern Texas.

DIPTERA. PHORIDÆ.

Aphiochæta nigriceps Loew.
Aphiochæta fasciata Fallen.
Aphiochæta pygmæa Zetterstedt.

These three species and also possibly others in this genus have frequently been found feeding upon boll-weevil larvæ and in many cases under such circumstances that they must be assumed to be parasites as well as scavengers.

TACHINIDÆ.

Myiophasia ænea Wiedemann.—This fly has been recorded as a parasite of the boll weevil in Texas. It is also an enemy of six other species of weevils.

Ennyomma globosa Townsend (Pl. XVIII, *d*, *e*).—This fly is an important parasite of the boll weevil in Louisiana. It also attacks the cowpea curculio.

Careful studies have proved that the 29 species of parasites are all derived from native hosts, which are mainly weevils breeding in weeds and other plants growing normally around the cotton fields. Some of these parasites have lived for many generations on certain common weevils until suddenly some abnormal condition has decimated the numbers of the normal hosts or freed the parasites of their normal control, thus upsetting the natural equilibrium between them and their hosts. In this way the parasites have been compelled to seek new hosts, and the presence of the boll weevil in large numbers has led them to attack it. This has been demonstrated by the sudden adaptation of several species of parasites at Victoria, Tex. These were normally enemies of the huisache pod weevil, but were unable to attack this insect in 1907 because of the failure of the huisache trees to fruit. Another demonstration of sudden adaptation was found in the sudden increase of attack by *Eurytoma tylodermatis* following the cutting of a number of weeds in which this parasite was attacking a native weevil. Such adaptability of course suggests the advisability of keeping the weeds in the vicinity of cotton fields cut down during the summer in order to force the parasites to attack the boll weevil.

After a parasite has once attacked a new host it becomes comparatively easy for succeeding generations to repeat the attack. In this manner many species of weevil parasites have increased their range of hosts until they have obtained a complete series extending throughout the year. A rotation of hosts has, therefore, been established. As many as 17 different weevils are attacked by one of the species of boll-weevil parasites. To illustrate the value of this rotation we have but to quote one of the commonest examples. The strawberry and blackberry bud weevil is very common in the South in the latter half of March and until June. Two of the species of the boll-weevil parasites attack this weevil as soon as it begins to breed, and they are able to develop at least one generation before the boll weevil can begin its attack on the cotton squares. These parasites are found attacking the boll weevil throughout the summer. In the fall they begin to attack certain stem weevils, such as the potato or Solanum stem weevils, and produce a generation during the winter which emerges in time to attack the strawberry weevil. Thus, two generations are developed while the boll weevil is in hibernation. To obtain a practical benefit from this rotation of hosts it is only necessary to have a hedge of dewberries or blackberries along the fences.

It is of extreme importance to know that no matter what exigencies reduce the boll weevils, the parasites, though also reduced in numbers, will still be conserved on their native hosts and will attack the boll weevils again as soon as they become sufficiently numerous.

The location of the developing stages of the weevil is of much importance to the insect enemies. (See Pl. XV.) It has been found that cotton varieties display two distinct tendencies in their response to injury to their fruit. Certain varieties, such as King, Simpkins, and Shine, are distinguished by a transverse ring at the base of the pedicel of the square and boll. When the square or boll is badly injured, the plant immediately cuts off circulation by forming a corky layer at this ring, and the injured member falls to the ground. Other varieties, such as Dickson, Rublee, and in general the cluster and semicluster types, are distinguished by an elliptical mark which encircles the pedicel, but extends down the stem for one-half to a whole inch or more, and is usually incomplete at the lower end. When such a square is injured, the corky layer is of course diagonal, extending downward on the stem, but usually incomplete, so that the injured member adheres by a thread of bark and dries on the plant. A very extended series of observations has definitely proved that the hanging dry infested square is the most favorable place for parasitic control and that the total control of the weevil by all causes increases in proportion to the number of these hanging dry infested squares. A proper selection of varieties is, therefore, a practical method of increasing control.

On the other hand, it must be understood that insect control of the stages in fallen squares is often very high. Certain parasites and all of the ants and predatory beetles are more likely to find the immature weevils in the soft moistened or dried fallen squares than in the dry hanging squares. Thus the developing weevil has enemies wherever it is. The parasite control on the ground will be obtained best by the methods of cultivation to be mentioned hereafter.

The adjustment of new species of parasites and predators in each new region makes it apparent that the boll weevil will everywhere be attacked by those species of insects most fitted to attack it under the existing local conditions. This attack will be of greatest importance in regions where humidity tends to reduce the effectiveness of other forms of control.

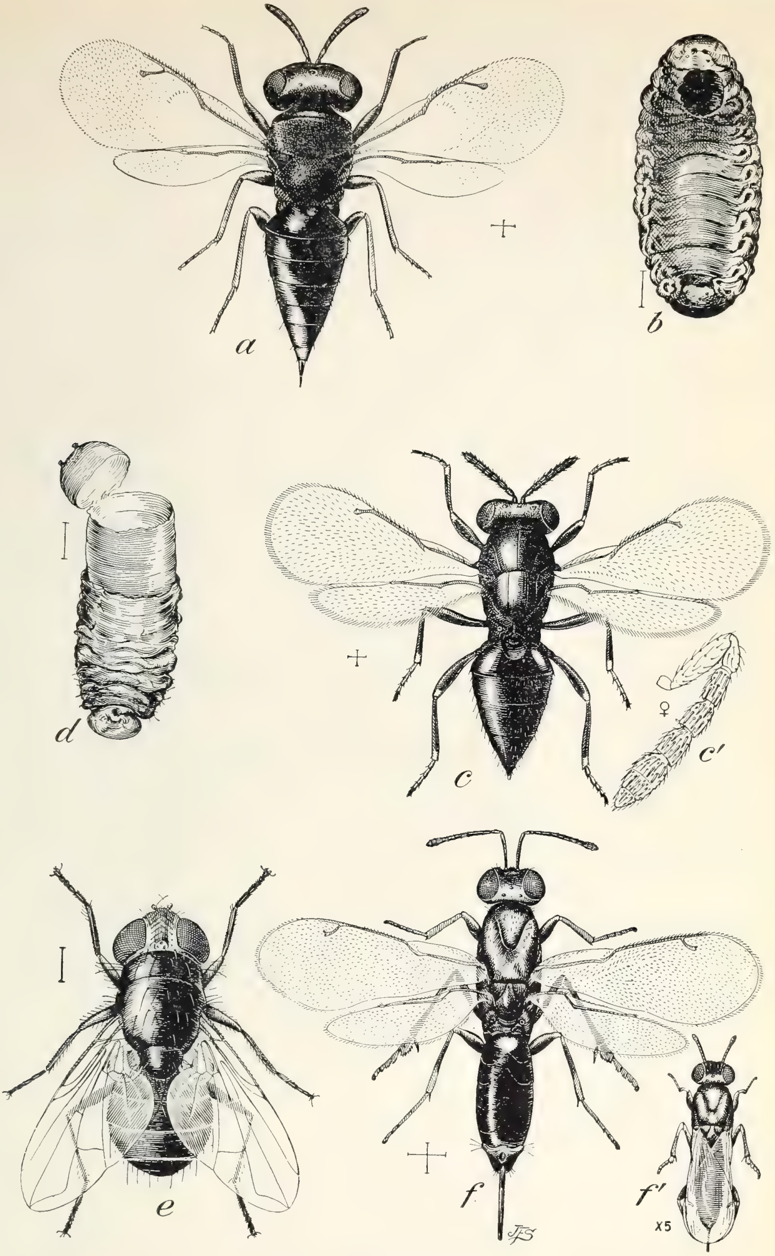
By Table LXIII we show the final summary of the records of parasitism made for a period of years to illustrate the fact that this is a factor of great importance.

TABLE LXIII.—*Parasite control of the boll weevil, by years.*

Year.	Weevil stages.	Parasites.	Mortality from parasites.
			Per cent.
1902	602	7	1.16
1903	819	59	7.20
1905, March	1,005	32	3.18
1905, August	1,702	21	1.23
1906	40,073	1,728	4.31
1907	13,602	1,121	8.24
1908	29,349	2,952	10.05
1909	11,653	620	5.32
Totals and average	98,805	6,540	6.61

Table LXIII is based upon collections of squares and bolls made throughout the infested territory under a great diversity of conditions.

The average monthly parasitic and predatory control for the years 1906 to 1909, inclusive, has been arranged below (Table LXIV) to show that insects are a factor of importance throughout the year. It should be noted especially that in the months of August and September, when the boll weevils are most numerous, from 27 to 30 per cent of the immature stages are killed by insect enemies. The average for the year of 25 per cent offers great encouragement.



BOLL-WEEVIL PARASITES.

a, *Lariophagus texanus*, female; *b*, emergence hole of *Tetrastichus hunteri* from weevil larva; *c*, *Tetrastichus hunteri*, female; *c′*, antenna of same; *d*, puparium of *Ennyomma globosa* in weevil larva; *e*, *Ennyomma globosa*; *f*, *Cerambycobius cyaniceps*, female; *f′*, natural position of same. (Original.)

TABLE LXIV.—*Weighted average insect control of immature stages of the boll weevil, by months.*

Month.	Forms examined.	Stages found.	Killed by parasites.	Percentage killed by parasites.	Killed by predators.	Percentage killed by predators.	Percentage killed by all insects.
January	5,687	1,285	54	4.20	63	4.90	9.10
February	13,597	665	56	8.42	60	9.02	17.44
March	2,500	159	2	1.25	28	17.61	18.86
May	100	56	2	3.57	0	.00	3.57
June	16,930	10,708	553	5.16	1,989	18.57	23.73
July	43,059	21,758	1,536	7.05	3,247	14.92	21.97
August	80,923	33,170	1,970	5.93	8,248	24.86	30.79
September	37,378	17,107	1,160	6.78	3,495	20.43	27.21
October	17,344	8,283	879	10.61	773	9.33	19.94
November	2,534	798	127	15.91	2	.25	16.16
December	2,663	688	82	11.91	14	2.03	13.94
Total	222,715	94,677	6,421		17,919		
Weighted average				6.78		18.92	25.70

The weighted average insect control in June, July, August, and September proves to be 26.82 per cent and for the remainder of the year 17.11 per cent.

A few records of high insect control will suffice to illustrate the extent of control under some conditions.

TABLE LXV.—*Highest records of insect control of the boll weevil.*

Places.	Date.	Location of squares.	Stages.	Killed by insects.
				Per cent.
Athens, Tex	Aug. 1, 1907	Fallen	255	96.11
Hallettsville, Tex	Aug. 1, 1908	...do	100	92.00
Overton, Tex	Aug. 1, 1906	...do	197	85.20
Athens, Tex	Aug. 1, 1907	Hanging	75	84.00
Beeville, Tex	Aug. 1, 1906	Fallen	1,310	78.80
Victoria, Tex	July 29, 1908	...do	375	78.38
Beeville, Tex	Sept. 1, 1906	...do	678	77.40
Arlington, Tex	July —, 1909	Hanging	55	75.44
Cuero, Tex	June 20, 1908	Fallen	549	73.60

The distribution of insect control in the four principal classes of forms, and also by geographical sections, has been presented in the general discussion of natural control.

BIRDS.

Exhaustive studies of the stomachs of many birds killed in infested cotton fields by the agents of the Biological Survey of this department have emphasized the fact that the birds play a considerable part in the control of the adult boll weevils. This investigation has resulted in a list of 53 species which more or less commonly feed upon the adult weevils. In Cuba, Mr. E. A. Schwarz discovered that an oriole (*Icterus hypomelas*) has developed a habit of extracting the immature stages from the bolls and squares.

Table LXVI, which follows, is taken from Circular 64 of the Bureau of Biological Survey.

Table LXVI.—*Schedule of stomach examinations of birds which had eaten boll weevils.*

Species.	During January, February, and March.			During April, May, and June.			During July, August, and September.			During October, November, and December.		
	Number of birds examined.	Number eating boll weevils.	Number of boll weevils eaten.	Number of birds examined.	Number eating boll weevils.	Number of boll weevils eaten.	Number of birds examined.	Number eating boll weevils.	Number of boll weevils eaten.	Number of birds examined.	Number eating boll weevils.	Number of boll weevils eaten.
Upland plover (*Bartramia longicauda*)	48	....	....	13	1	1	1	....	....	....	....	....
Killdeer (*Oxyechus vociferus*)	28	2	5	1	....	....	6	....	....	1	....	....
Quail (*Colinus virginianus*)	63	....	....	10	....	....	38	....	....	108	1	1
Nighthawk (*Chordeiles virginianus*)	....	....	....	....	....	....	10	4	15	....	....	....
Scissor-tailed flycatcher (*Muscivora forficata*)	....	....	....	....	....	....	91	5	7	....	....	....
Kingbird (*Tyrannus tyrannus*)	....	....	....	10	1	1	22	6	8	....	....	....
Crested flycatcher (*Myiarchus crinitus*)	....	....	....	7	1	2	5	1	3	....	....	....
Phœbe (*Sayornis phœbe*)	19	....	....	....	....	....	2	1	1	13	3	3
Olive-sided flycatcher (*Nuttallornis borealis*)	....	....	....	....	....	....	2	1	2	....	....	....
Alder flycatcher (*Empidonax trailli alnorum*)	....	....	....	....	....	....	3	1	2	....	....	....
Least flycatcher (*Empidonax minimus*)	....	....	....	....	....	....	14	7	21	....	....	....
Blue jay (*Cyanocitta cristata*)	8	1	1	1	....	....	1	....	....	2	....	....
Cowbird (*Molothrus ater*)	92	4	4	....	....	....	84	3	3	24	....	....
Red-winged blackbird (*Agelaius phœniceus*)	79	4	5	16	1	1	11	....	....	49	2	2
Meadowlark (*Sturnella magna*)	48	10	18	1	....	....	1	....	....	183	28	32
Western meadow lark (*Sturnella neglecta*)	52	8	11	....	....	....	....	....	....	66	12	18
Orchard oriole (*Icterus spurius*)	....	....	....	20	1	1	101	30	64	....	....	....
Baltimore oriole (*Icterus galbula*)	....	....	....	2	....	....	50	11	24	....	....	....
Bullock oriole (*Icterus bullocki*)	....	....	....	....	....	....	149	40	133	....	....	....
Rusty blackbird (*Euphagus carolinus*)	6	1	1	....	....	....	....	....	....	10	....	....
Brewer blackbird (*Euphagus cyanocephalus*)	139	24	40	1	....	....	....	....	....	5	2	2
Bronzed grackle (*Quiscalus q. æneus*)	36	5	5	19	....	....	3	....	....	3	....	....
Great-tailed grackle (*Megaquiscalus major macrourus*)	32	2	2	7	1	1	6	....	....	2	....	....
Vesper sparrow (*Poœcetes gramineus*)	29	1	1	....	....	....	....	....	....	11	....	....
Savanna sparrow (*Passerculus sandwichensis*, subspecies)	68	8	15	2	....	....	....	....	....	18	1	1
Lark sparrow (*Chondestes grammacus*)	....	....	....	13	....	....	54	1	1	....	....	....
White-throated sparrow (*Zonotrichia albicollis*)	53	1	1	4	....	....	....	....	....	9	1	1
Field sparrow (*Spizella pusilla*)	25	2	2	....	....	....	5	....	....	....	....	....
Swamp sparrow (*Melospiza georgiana*)	27	1	2	....	....	....	....	....	....	....	....	....
Fox sparrow (*Passerella iliaca*)	8	1	2	....	....	....	....	....	....	9	....	....
Towhee (*Pipilo erythrophthalmus*)	10	1	1	1	....	....	....	....	....	6	....	....
Cardinal (*Cardinalis cardinalis*)	42	....	....	7	....	....	39	3	4	....	....	....
Texan pyrrhuloxia (*Pyrrhuloxia s. texana*)	....	....	....	....	....	....	64	2	2	....	....	....
Painted bunting (*Passerina ciris*)	....	....	....	....	....	....	109	18	19	....	....	....
Dickcissel (*Spiza americana*)	....	....	....	1	....	....	26	3	3	....	....	....
Purple martin (*Progne subis*)	....	....	....	15	1	1	5	1	1	....	....	....
Cliff swallow (*Petrochelidon lunifrons*)	1	....	....	1	....	....	35	34	638	....	....	....
Barn swallow (*Hirundo erythrogastra*)	....	....	....	....	....	....	14	5	52	16	....	....
Bank swallow (*Riparia riparia*)	....	....	....	....	....	....	25	11	68	....	....	....
Loggerhead shrike (*Lanius ludovicianus*)	46	1	4	4	....	....	19	....	....	12	2	5
Yellow warbler (*Dendroica æstiva*)	....	....	....	....	....	....	25	1	1	....	....	....
Myrtle warbler (*Dendroica coronata*)	17	1	2	3	....	....	....	....	....	....	....	....
Maryland yellowthroat (*Geothlypis trichas*)	2	1	1	1	....	....	1	....	....	....	....	....
Yellow-breasted chat (*Icteria virens*)	....	....	....	....	....	....	5	1	1	....	....	....
American pipit (*Anthus pensilvanicus*)	73	34	120	....	....	....	....	....	....	8	3	4
Mockingbird (*Mimus polyglottos*)	43	2	2	13	....	....	85	5	5	5	....	....
Brown thrasher (*Toxostoma rufum*)	9	....	....	7	....	....	....	....	....	29	1	1
Carolina wren (*Thryothorus ludovicianus*)	37	6	9	31	1	2	1	....	....	7	5	6
Bewick wren (*Thryomanes bewicki*)	11	1	3	....	....	....	3	....	....	2	....	....
Winter wren (*Nannus hyemalis*)	1	1	2	....	....	....	....	....	....	....	....	....
Tufted titmouse (*Bæolophus bicolor*)	14	5	7	23	....	....	....	....	....	....	....	....
Black-crested titmouse (*Bæolophus atricristatus*)	....	....	....	....	....	....	1	....	....	2	1	1
Carolina chickadee (*Penthestes carolinensis*)	6	1	1	....	....	....	1	....	....	1	....	....

It will be noticed that the largest numbers of boll weevils were eaten during the months of July, August, and September, and also that a considerable number are consumed during the hibernating season. The most important birds are those that capture the boll weevil during the winter. According to this table these are the three species of blackbirds, two meadowlarks, six species of native sparrows, the pipit, the three species of wrens, and the two species of titmice. It will be noted that only one of the 108 quail stomachs examined showed remains of the boll weevil.

REPRESSION.

EFFECT OF BURIAL OF SQUARES AND WEEVILS.

The effect of the burial of squares and weevils is of considerable importance for the reason that some degree of burial can be practiced in the ordinary processes of cultivation. If it were to be found that the weevils could be killed by a depth of burial which could be accomplished without interference with the root system of the plants this process would be of vast importance.

At Tallulah, La., in 1910, Mr. G. D. Smith conducted an extensive series of burial experiments. The infested squares were placed in screened cages in the field. In each of these cages 2,000 infested squares were placed on October 10. A careful estimate showed that there were 250 live weevil stages for each 2,000 squares. In the first of the cages the infested squares were placed upon a sheet of wire screen 2 feet above the ground. These squares were kept constantly moist. In the second cage the squares were placed on the surface of the ground. No artificial moisture was supplied. In the third cage the squares were on the surface of the ground but were kept moist constantly. In the fourth cage the squares were buried to a depth of 2 inches and the ground was kept moist. In the fifth cage the squares were buried 4 inches and the ground was kept dry. The artificial moisture was applied three times each day during the course of the experiment. The "dry" cages were covered with canvas so that rains could not reach the squares. The soil in the locality was the typical "buckshot" of the Mississippi Delta. Immediately before the institution of the experiments several rains had made the soil moist. Observations on emergence were made from October 10 until November 15.

Table LXVII summarizes the results of these experiments.

TABLE LXVII.—*Summary of experiments in the burial of squares infested by the boll weevil at Tallulah, La., October and November, 1910.*

	Conditions.	Emergence (weevils).	Emergence.
			Per cent.
Cage 1	2 feet above surface, moist	119	47.6
Cage 2	On surface, dry	157	62.8
Cage 3	On surface, moist	147	58.8
Cage 4	Buried 2 inches, dry	62	24.8
Cage 5	Buried 2 inches, moist	6	.2
Cage 6	Buried 4 inches, dry	18	.7
Cage 7	Buried 4 inches, moist	0	.0

It will be noticed that the greatest emergence was from the two cages in which the squares were placed upon the surface of the ground. At 2 and 4 inches beneath the surface the emergence was very small. When kept dry beneath 2 inches of the soil 24 per cent of the possible emergence occurred, but at this depth when moisture was provided less than 1 per cent emerged. At a depth of 4 inches 0.7 per cent emerged in the dry cage, but none from the same depth where moisture was provided. It may be concluded from these experiments that burial beneath 2 or more inches of dry soil of the "buckshot" variety will prevent the emergence of a large portion of the weevils. If the soil is kept moist with burial at 2 inches or more below the surface the emergence is practically negligible. This is shown most clearly by comparing cages 4 and 5 in the table.

LABORATORY EXPERIMENTS IN BURIAL.

In an experiment performed at Victoria, Tex., in 1904, 1,000 infested squares were buried under from 2 to 5 inches of well-pulverized earth.[1] Seventy-five weevils emerged. Twenty-seven weevils were found which had been unable to reach the surface. Their location varied from the bottom of the receptacle to just beneath the surface. The weighted average of the distances covered by the weevils which failed to reach the surface was 2 inches.

In another series of experiments at Victoria, Tex., 74 squares were placed under wet soil. It was found that 16 per cent of the weevil stages were killed. Of the weevils which became adult 30 per cent emerged from the squares, but only 23 per cent reached the surface or escaped from an average depth of 1 inch. In these experiments, considering all the weevil stages present, 35 per cent died without escaping from the soil.

In 1904 Prof. E. D. Sanderson performed a number of burial experiments at College Station, Tex. At from 0.5 inch to 1.5 inches below the surface 26.7 per cent of the weevils emerged; at from 2 to 4 inches 4.7 per cent reached the surface.

It will be noted that these laboratory experiments substantiate the conclusion drawn from the field experiments described previously regarding the greatly increased mortality brought about by deep burial and by moisture.

BURIAL OF ADULT WEEVILS AT TIME OF HIBERNATION.

On or after November 23, 1903, at Victoria, Tex., 1,000 adult weevils were buried under from 2 to 6 inches of soil which contained from 9 to 19 per cent of water. Only five of these weevils succeeded in reaching the surface. Four of those which escaped and one which was still buried in the earth were found alive when examination was made on March 16, 1904. All the remaining weevils appear to have died where they were buried.

CONCLUSIONS FROM BURIAL EXPERIMENTS.

The field and laboratory experiments to which references have been made indicate that the boll weevil has comparatively little ability to emerge from moist soil, while dry, partially pulverized soil offers small obstacles to their emergence. The experiments also show that burial, even under moist conditions, would have to be as deep as 2 inches to bring about very decided results. The practical question therefore is whether in cotton fields the soil can be turned over to a depth of 2 inches during the growing season without injury to the crop. As is well known, one of the most important cultural methods in producing cotton is shallow cultivation. The reason for this is that the plant sends many lateral roots almost at right angles from the rows and at a very short distance beneath the surface. Many of these lateral roots lie only 2 or 3 inches beneath the ground. If they were disturbed, the plants would react by shedding the squares. Undoubtedly the loss of fruit from this cause would more than offset any possible advantage accruing from the destruction of the

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[1] Much more thoroughly pulverized than would be the case in the field.

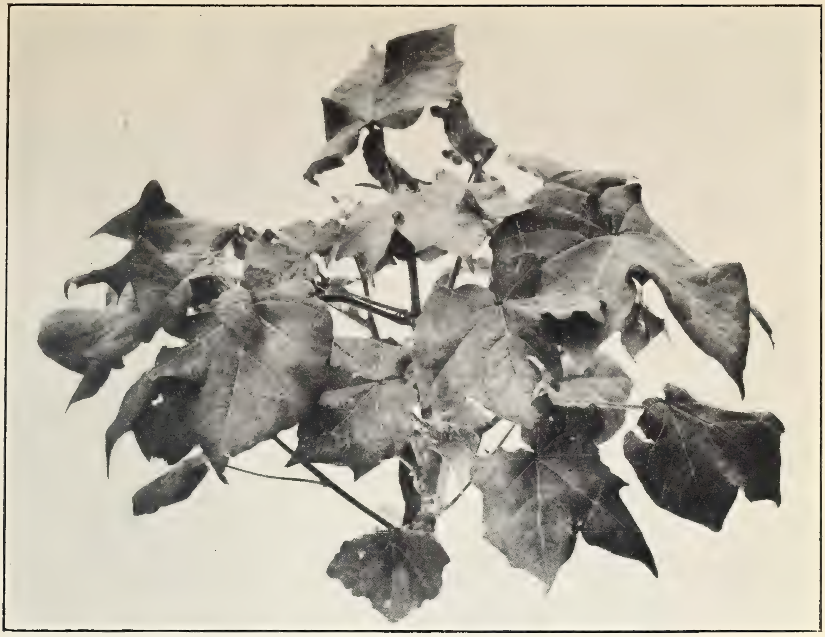

Fig. a.—Cotton before treatment with Paris green. (Original.)

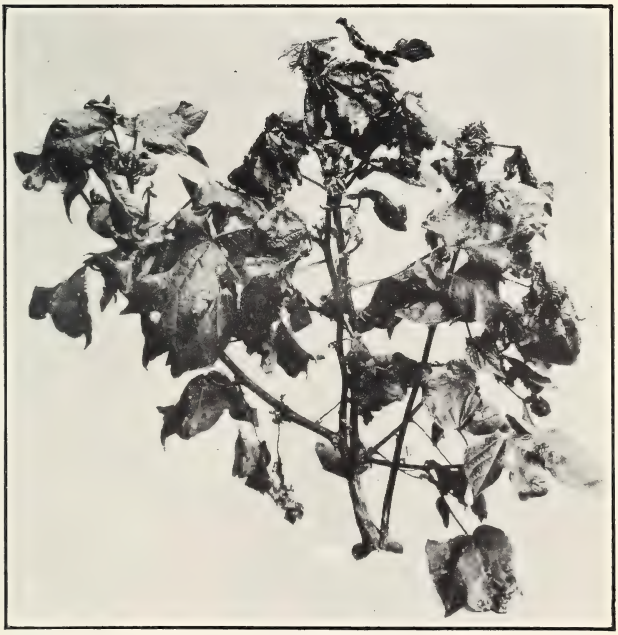

Fig. b.—Cotton one week after treatment with Paris green. (Original.)

EFFECT OF PARIS GREEN ON COTTON.

weevils by burial. It is thus clear that as a means of controlling the weevil during the growing season the burial of squares is impracticable. There is a time, however, when the burial of the squares can be carried on to excellent advantage. This is in the fall when the maximum infestation has been reached. Under these conditions it makes no difference to the planter whether the lateral roots of the cotton plant are cut or not. The fruit already set on the plants will develop in either case, and any additional fruit inevitably will be destroyed by the insects. Consequently the planter may destroy many of the weevils which would mature in a short time to feed, multiply, and enter hibernation, to emerge and damage the crop of the succeeding season. In this way deep fall cultivation is a preliminary step that should be practiced in connection with the destruction of the plants. It should precede that process and should by no means be depended upon to take the place of it. After the plants have been uprooted and brought into windrows previous to burning it is advisable to plow the fields to a depth of at least 2 inches. This will result in the burial of many squares which were on the ground at the time of the uprooting or which fell during the process. The experiments show that the effectiveness of burial either before or after the uprooting of the plants will increase greatly if rains occur after the work is done. Likewise it is evident that the destruction of the weevils will be much greater in heavy soils than in lighter formations. In the Mississippi-Yazoo Delta the general nature of the soils is more or less heavy. This and the heavy precipitation in that region indicate a means of destroying the weevil that is especially important on account of the scarcity of direct means available.

INSECTICIDES.[1]

From the very beginning of the work on the boll weevil much attention has been given to testing the more promising insecticides. As one result of the offer of a $50,000 prize by the State of Texas for an efficient remedy for the boll weevil, large numbers of supposed remedies have been proposed. Doubtless the inventors have been perfectly sincere in their faith in the efficiency of these compounds. As was fully anticipated by the entomologists when the reward was offered, the commission charged with awarding the money was deluged with applications therefor, the claims in a large majority of cases being based upon some concoction supposed by the inventor to possess marvelous insecticidal properties. In comparatively few cases had the new product been tested in any way. Often samples were sent with the request that tests be made. Many of these inventions found their way to the various laboratories of this investigation, where it has been the uniform policy to give every thing of this kind a fair test and report the results to the originator. Tests were made in the field upon weevils confined by cages. This work has required a great deal of time, and the results have failed to indicate a single new compound having real value. Many of the substances tried had absolutely no effect on either plant or insect life, while others were equally fatal to both wherever they came in contact with them. The primary difficulty with all such insecticides lies in the fact that, owing to the peculiar habits and life history of the weevil, the poison can not be so applied as to reach the immature stages at all, and it can not reach the adults so as to cause sufficient mortality to result in any considerable benefit to the crop. Much work has been done in thoroughly testing the effect of Paris green. The most important results of this work have already been published in Farmers' Bulletin No. 211 of the Department of Agriculture. They will be described briefly on a subsequent page.

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[1] The first two paragraphs under this heading have been modified from Bull. 51, Bureau of Entomology, p. 156.

Among 40 other compounds tested, none proved worthy of even passing consideration for field use. As a fumigant for seed, among the eight gases or vapors tested, carbon bisulphid was found to possess considerable value when applied in the special manner described on pages 162, 163.

POWDERED ARSENATE OF LEAD.

In 1909 Messrs. Wilmon Newell and G. D. Smith, then of the Louisiana Crop Pest Commission, published the results of certain work with powdered arsenate of lead as a remedy against the boll weevil. This work was done in central Louisiana during the season of 1909. The principal experiments were located on three different plantations on plats provided for the purpose. From 1 to 10 applications were made, consisting of a total amount of poison of from 1 to 51 pounds per acre. The treated cotton yielded an average of 71 per cent more than similar cotton which was not treated. In all except one of the plats there was a net profit from the use of the poison (that is, after deducting the cost of the poison and of the labor from the value of the increased yield) of from 27 cents to $23.54 per acre. In the one exception there was a loss of $7.07 per acre.

These striking results led to extensive work on powdered arsenate of lead by the Bureau of Entomology. The services of Mr. G. D. Smith, who was directly connected with the Louisiana work to which reference has been made, were obtained. The bureau instituted numerous experiments in Louisiana, including several which duplicated the previous work in that State. This investigation has now extended through two seasons in Louisiana, and considerable work has also been done at Victoria, Tex., by Mr. J. D. Mitchell.

In the experiments of 1910, 32 plats were utilized on plantations at Livonia, Shaw, and St. Joseph, La., and Victoria, Tex. In the work in Louisiana there was a profit from the use of the poison on 20 of the plats and a loss on the 12 remaining plats. The average loss on the plats which failed to show a profit was $6.99 per acre. The average profit on the remaining plats was $5.83 per acre. Twenty-two of the 32 plats showed an increased yield of from 35 pounds to 403 pounds of seed cotton per acre. A striking result was the fact that invariably the plats upon which small amounts of the poison were applied showed profits. The work at Victoria, Tex., in 1910, consisted of four experiments. In only one of these experiments was a gain in yield obtained, and this amounted to only 59 pounds of seed cotton per acre. In all of the experiments at this place there was a loss from the application of the poison of from $1.55 to $6.52 per acre.

In 1911 the work on powdered arsenate of lead was continued. In some respects the results were contradictory of those obtained previously, but there was agreement in that profits were obtained on all plats where small applications were made. On account of the apparent contradictions and the variations due to the seasons it is considered necessary to continue the work another season before definite conclusions as to the practical value of arsenate of lead can be drawn.

MACHINES.

FIELD MACHINERY.

Many attempts have been made to perfect machines that will assist in the warfare against the weevil. The only one of direct value that has been perfected is the chain cultivator (Pl. XX, *b;* Pl. XXI) invented by Dr. W. E. Hinds, formerly of the Bureau of Entomology, and patented by the Department of Agriculture for the benefit of the people of the United States. Its construction is based upon the discovery that the weevils in the infested squares that fall in such position as to be reached by the sun soon die. In a cotton field many of the infested squares fall within the shade of the plants, and are thus protected. The chain cultivator is designed to drag the fallen squares to the middles of the rows and leave them exposed to the sun. This it has been found to accomplish in a satisfactory manner. In fact, in tests the use of the machine has been found to result in a decided gain in production.

Although the chain cultivator was designed primarily for bringing the squares to the middles, it was found in field practice to have a most important cultural effect. The chains (so-called "log chains") are heavy enough to establish a perfect dust mulch and to destroy small weeds that may be starting. In fact, it is believed that this cultural effect would more than justify the use of the machine, regardless of the weevil. In view of the effect against the insect and the important cultural effect, it is believed that this implement or one similar to it should be used by every farmer in the weevil territory.

The chain cultivator is now regularly manufactured by one of the large dealers in farm implements, but a satisfactory machine can be made by any blacksmith. Full directions are to be found in Farmers' Bulletin 344, a copy of which may be obtained upon application to the Secretary of Agriculture.

Some forms of cultivators now in use allow the attachment of boards which drag on the ground and carry the infested squares to the middles. In fact, the principle of the chain cultivator can be incorporated in many implements now in use. It is strongly recommended that this be done for weevil control as well as for obtaining a dust mulch.

[1] Many machines have been designed to jar the weevils and infested squares from the plant and to collect them, to pick the fallen squares from the ground, to kill by fumigation, and to burn all infested material on the ground. The Bureau of Entomology has carefully investigated the merits of representatives of all of these classes, beginning in 1895 with a square-collecting machine that had attracted considerable local attention in Bee County, Tex. Up to the present time none of these devices has been found to be practical or to offer any definite hope of being eventually successful. At one

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[1] The following three paragraphs are modified from Bull. 51, Bureau of Entomology, p. 157.

time there seemed some hope that a machine designed to pick the squares from the ground by suction might be perfected. The experiments, however, have indicated probably insurmountable difficulties; and a large implement concern, after having experimented with the matter fully, has come to the conclusion that mechanical difficulties will always prevent the perfection of such a machine.

The ultimate test of all methods or devices for controlling the weevil is to prove through a series of seasons, and under a large variety of conditions, that by their use there is produced an increase in the crop treated or protected of sufficient value to more than repay the expenses of the treatment or protection. As a general rule, where machines have been used or poisons applied, planters have provided no check upon the results obtained and have kept no close records as to the expense involved and net gain or loss resulting from the treatment. The result of such applications is, therefore, merely a general impression of gain or loss which may not agree at all with the facts.

In this connection it must be stated that all machines which assist in more satisfactory methods of preparation of the land and cultivation of the crop are of indirect advantage. This is especially the case with devices which increase the amount of work that a single hand or team of mules may do. In fact, the boll weevil has been the cause of much commendable improvement of agricultural machinery throughout the infested territory.

GINNING MACHINERY.[1]

The more important results of studies upon this class of machinery were presented in Farmers' Bulletin No. 209 of the Department of Agriculture. Modern cleaner feeders were found to be quite efficient in separating the weevils from the seed cotton, as they removed fully 70 per cent of the weevils passing into them. Of the weevils removed, over 80 per cent were still alive when taken from the trash. This fact shows the necessity for the use of some additional device which will crush or otherwise destroy all weevils taken from the cotton by the cleaner feeder. (See Pl. X, *a*.)

For the weevils escaping the action of the cleaner feeder and passing into the ginning breast with the roll there are two avenues of escape—one with the seed, the other with the motes. In these two ways it appears that over 85 per cent of the weevils passing into the gin breast escape alive, while the remainder are killed by the saws. From these facts it is evident that some way should be provided for properly caring for the motes so as to confine the weevils which are thrown out among them and secure their destruction with those removed by the cleaner feeder. Some method should also be devised for separating from the seed the weevils that pass the saws before they reach the seed house or the farmers' seed bins.

When we consider the important effect that gins have been found to possess in spreading the weevil, especially near the border line of infestation, it appears exceedingly desirable that improvements in gin machinery should be made in the following particulars:

First. The area and distance through which the action of the picker roll in the cleaner feeder is continued should be considerably increased,

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[1] This section is modified from Bull. 51, Bureau of Entomology, pp. 158, 159.

Fig. a.—Early fall destruction of stalks, the fundamental method for controlling the boll weevil. Windrowing stalks for burning. (Original.)

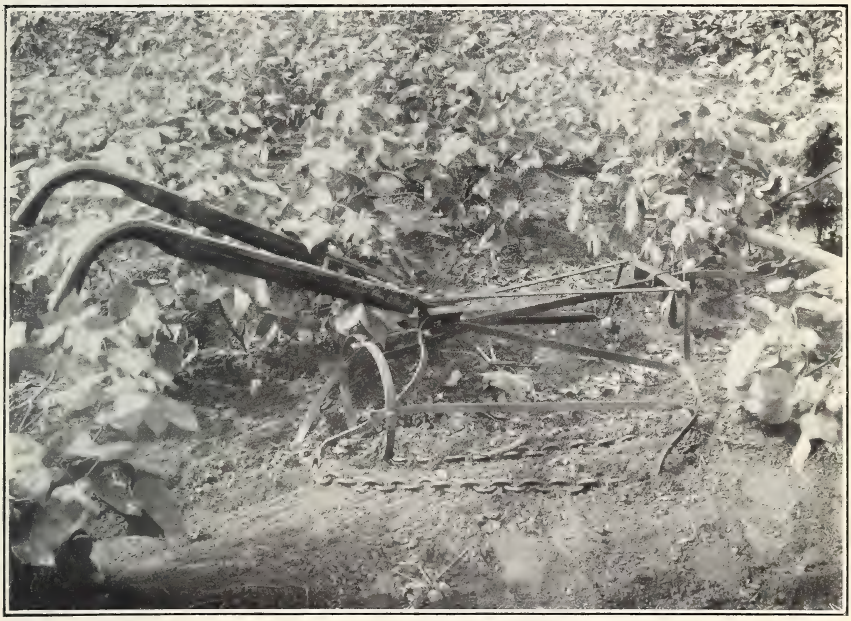

Fig. b.—Chain cultivator passing through cotton rows. (Original.)

CULTURAL CONTROL OF THE BOLL WEEVIL.

Fig. a.—Space between cotton rows before passage of cultivator. (Original.)

Fig. b.—Effect after passage of cultivator. (Original.)

USE OF CHAIN CULTIVATOR.

compression rollers or some other device being employed to destroy the weevils separated by the cleaner.

Second. Some method should be devised for keeping under control the weevils escaping alive with the motes, as under present conditions they have free range through the ginnery.

Third. Possibly the most important of the devices needed is an apparatus which may be applied near the gin (possibly as the seeds leave the gin breast and drop into the seed chute) by which the weevils may be separated from the seed and brought under control, so that they may be destroyed.

With these improvements the oil mills would almost cease to be a factor in the dissemination of weevils, and the movement of seed, either for planting, stock feeding, or fertilizer, would practically cease to be what it is at present, a factor in the spread of the weevil.

FUTILE METHODS WHICH HAVE BEEN SUGGESTED.[1]

MINERAL PAINT AND COTTONSEED OIL.

The very serious nature of the boll-weevil problem is constantly illustrated by the manner in which various useless devices and nostrums are brought to public attention. At one time it was widely alleged that mineral paint would act as a specific against the weevil. An equally fallacious theory that also received considerable popular attention was to the effect that cottonseed meal exerted a powerful attraction for the pest.

SPRAYING.

Probably the most important useless recommendation has been that of spraying. It was supposed for some time by certain parties that it might be possible to poison weevils economically by attracting them to some sweetened preparation. The experiments conducted to determine the attraction of various sweetened substances demonstrate the fallacy of the theory. Even if these substances exerted as much attraction as was supposed, there would be insurmountable difficulties in the application of the method in the field. It is true that it is possible to destroy a certain number of weevils in regions where stubble cotton occurs by heavily spraying the earliest plants, but this method is of immeasurably less importance than the simple practice of cultural methods.

SULPHUR.

The old idea, the fallacy of which has been explained repeatedly by economic entomologists for the past 50 years, namely, that sulphur can be forced into the system of the plants to make them immune to insect attack, sometimes crops out with reference to the boll weevil. It is scarcely necessary to call attention to the fallacy of attempting to destroy the boll weevil by soaking the seed in chemicals with the hope of making the plants that are to grow from them distasteful or poisonous to the insect. Any money expended by the farmer in following this absurd practice is entirely wasted.

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[1] This section is greatly modified from Bull. 51, Bureau of Entomology, pp. 159, 160.

PARIS GREEN.

One of the most important fallacies regarding a remedy for the boll weevil was that which received great attention during the season of 1904, namely, that Paris green is a specific for the pest. The urgent demand for a specific was evidenced by the very extensive use of this substance. A portion of the great attention that it received publicly was due to the fact that early in the season a certain number of weevils may be killed by it. Applications made by spraying are even less effective than dusting with the dry Paris green. As was pointed out in Farmers' Bulletin No. 211, which deals with exhaustive field and laboratory experiments with Paris green, the number so destroyed in the spring really means nothing whatever to the crop later in the season when the plants have put on squares and the poison is no longer effective. As a matter of fact, the uselessness of Paris green was quickly discovered by planters. Since 1904 practically none has been used in the warfare against the pest. (See Pl. XIX.)

TRAPPING AT LIGHT.

There is still, in many quarters in Texas and Louisiana, a supposition that it is possible to attract the boll weevil to lights. A number of machines have been constructed based upon this idea. Whether or not the boll weevil can be attracted to lights was one of the first matters that was investigated by entomologists. During September, 1897, Mr. J. D. Mitchell, of Victoria, Tex., a naturalist and cotton planter, set out trap lanterns in a cotton field in Victoria for one night, and sent the insects captured to this bureau for examination. In all, 24,492 specimens were taken, representing approximately 328 species. Divided according to habit, whether injurious or beneficial, the result was: Injurious species, 13,113 specimens; beneficial species, 8,262 specimens; of a negative character, 3,117. The interesting point in connection with this experiment was the fact that not a single specimen of the boll weevil was found, although the lights were placed in the midst of fields where the insects were very abundant. Since that time other investigators have looked into this matter fully. Lights have been kept burning in cotton fields night after night for several weeks. In no case has a single specimen of the boll weevil been discovered, although thousands of species of insects have been captured.

The popular misapprehension about the possibility of capturing the boll weevil at lights is due to the fact that somewhat similar insects, *Balaninus victoriensis*, and other acorn weevils, differ from the boll weevil in that lights exert a strong attraction for them. During occasional seasons the acorn weevils are exceedingly common in Texas, and great numbers of them fly to the electric lights.

OTHER PROPOSED REMEDIES.

Hundreds of proposed remedies, in addition to those which have been mentioned, have been carefully investigated. The claims of their advocates in practically all cases are based upon faulty observations or careless experiments. The strong tendency of the weevil to die in confinement, which has been referred to, has caused many honest persons to suppose that the substances they are applying have killed it. Moreover, an insuperable difficulty that these special preparations have encountered is the impracticability of the application in the field. Hundreds of known substances will kill the weevil when brought into contact with it. The difficulty is to apply them in an economical way in the field. The claims made at different times of the repellent power of tobacco, castor-bean plants, and pepper plants against the boll weevil have no foundation whatever. In fact, none of these plants has the least effect in keeping weevils away from cotton.

REQUIREMENTS OF A SATISFACTORY METHOD OF BOLL-WEEVIL CONTROL.[1]

The difficulties in the way of controlling the boll weevil lie both in its habits and manner of work and also in the peculiar industrial conditions involved in the production of the staple in the Southern States. The facts that in all stages, except the imago, the weevil lives within the fruit of the plant, well protected from any poisons that might be applied, and in that stage takes food normally only by inserting its snout within the substance of the plant; that it frequently requires only 12 days for development from egg to adult, and the progeny of a single pair in a season may exceed 3,000,000 individuals; that it adapts itself to climatic conditions to the extent that the egg stage alone in November may occupy as much time as all the immature stages together in July or August, are factors that combine to make it one of the most difficult insects to control. It is, consequently, natural that all the investigations of the Bureau of Entomology have pointed toward the prime importance of methods of control which involve no outlay for materials and very little for labor. Methods which involve some direct financial outlay for material or machinery are not in accord with labor conditions surrounding cotton production in the United States. Moreover, the indirect methods advocated are in keeping with the general tendency of cotton culture; that is, to procure an early crop, and at the same time have the great advantage of avoiding damage by a large number of other destructive insects, especially the bollworm. Nevertheless it must not be understood that attention has not been paid to the investigation of means looking toward the direct extermination of the pest. Much work has been done, but the results have all been negative.

BASIS FOR MEANS OF REPRESSION.

In spite of the many difficulties involved in the control of the boll weevil certain generally satisfactory means of repression are at hand. They consist of both direct and indirect means. Those of an indirect nature are designed to increase the advantage gained by the direct measures and to increase the effectiveness of the several natural factors which serve to reduce the number of weevils. Thus, the control measures constitute a combination of expedients, the parts of which interact in many ways. Naturally, the best results are obtained when the planter can put into practice all of the essential parts of the combination.

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[1] This section is greatly modified from Bull. 51, Bureau of Entomology, pp. 160, 161.

It is obvious that any method of controlling the boll weevil must depend upon full knowledge regarding its life history and the natural forces which tend to prevent its multiplication. Certain practices which upon superficial observation might be considered important in the control of the insect upon investigation may be found to be of no avail whatever. In fact, in some cases what appear to be feasible means of control are worse than useless, because they tend to nullify the effects of natural forces which act against the weevil. This is notably the case with the practice of attaching a bar to a cultivator to jar the infested squares from the plants. As will be explained later, this practice is of advantage only under very restricted conditions. Throughout the greater part of the infested territory it is an assistance rather than a hindrance to the boll weevil.

There are seven features of the life history of the weevil that are of cardinal importance in control. These are indicated below.

1. The weevil has no food plant but cotton.
2. The mortality of the weevil during the winter is very high.
3. The emergence from hibernating quarters during the spring is slow and prolonged until well into the summer.
4. Early in the season, on account of comparatively low temperatures, the development of the weevil is much slower than during the summer months.
5. The drying of the infested squares, as the result of heat, soon destroys the immature stages of the weevil contained therein.
6. The weevil is attacked by many different species of insect enemies, the effectiveness of which is increased by certain practices.
7. The weevil has but little ability to emerge when buried under wet soil.

Exactly how each of these features of the life history of the weevil affects plans for practical control will be explained in the following paragraphs.

In the case of many of the important injurious insects the problem of control is greatly complicated by the fact that the pests can subsist upon more than one food plant. In some cases a single species attacks several cultivated crops. In other cases the pests can subsist upon native plants practically as well as upon the cultivated species. All these difficulties are absent in the case of the boll-weevil problem. As has been shown in the preceding pages, the insect is absolutely restricted to the cotton plant for food and for opportunities for breeding. The problem is therefore much more simple than it would be if the weevil could subsist upon any other plant in the absence of cotton. This peculiarity of the weevil was the basis of the recommendation made in 1894 that the pest be exterminated absolutely in the United States by the abandonment of cotton. At that time only a few counties in Texas were affected. The procedure would have involved small expense. Even now the weevil could be exterminated in a single season by preventing the planting of cotton and the growth of volunteer plants. This proposal has been made at various times, notably at the national boll-weevil convention held in Shreveport, La., in 1906.

Various difficulties, however, appear to render the plan entirely impracticable. In the first place, there would be strong opposition in large regions in Texas where the planters have learned to combat the weevil successfully. This opposition would undoubtedly be sufficiently strong to prevent cooperation in a large territory. Moreover, the expense would be enormous. A large army of inspectors would be required. The work would not end with the prevention of planting cotton, but would necessarily extend to the destruction of volunteer plants which would be found along roads, railroads, about gins and oil mills, and on plantations throughout the infested region. The loss to mills, railroads, merchants, banks, and others dependent upon the cotton trade would complicate matters further. Unless a plan of reimbursement were followed there would be strenuous opposition from these quarters, and any scheme of payment for damages would increase the cost still further. From a theoretical standpoint all the expenses involved would be justified. The saving in a few years would more than offset the cost. Nevertheless, the practical difficulties undoubtedly will always prevent the execution of the plan. All interests now seem to favor the necessary adjustment of conditions to the boll weevil rather than total eradication—once practicable but now little more than visionary.

Under the discussion of the hibernation of the weevil it was shown that during the several years in which careful experiments have been performed the average rate of survival was 7.6 per cent. It is noteworthy that frequently the survival is much smaller. In the experiments to which reference has been made it ranged from 0.5 per cent to 20 per cent. The most important means of controlling the boll weevil that are available are designed to increase the tremendous mortality caused by natural conditions during the winter. The destruction of any certain number of weevils during the winter is much more important than the destruction of much larger numbers at any other season. The best means at the command of the farmer for increasing the winter mortality is through the uprooting and burning or burial of the stalks at an early date in the fall. (See Pl. XX, *a*.) Numerous experiments have shown the lessened mortality due to depriving the weevils of their food at early dates in the autumn. In fact, the experiments showed a practically uniform increase in the number of weevils surviving as the dates of the destruction of the plants became later. For instance, in all of the experiments performed in Texas it was found that destruction in September resulted in a survival of only 0.2 per cent; destruction two weeks later showed a survival of 2.3 per cent; destruction during the last half of October, 5.6 per cent; and during the first half of November, 15.4 per cent. The results of the Louisiana experiments were similar. Destruction in September showed a survival of 0.3 per cent; destruction in the first half of October, 2 per cent; in the last half of October, 8 per cent.

In addition to the experiments in which the weevils have been placed in cages at different times in the fall, the Bureau of Entomology has conducted considerable field work to show the benefits of fall destruction. The most striking experiment was performed at Calhoun County, Tex., in 1906. In this experiment an isolated area of over 400 acres of cotton was utilized. There was no other cotton within a distance of 15 miles. By contracts entered into by the department, the farmers uprooted and burned all of the stalks during the first 10 days in October, and provision was made to prevent the growing of sprout cotton. As a check against this area, cotton lands about 30 miles away were used. Here the stalks were not destroyed in the fall, and the interpretation of the results of the experiment was based upon a comparison of the number of weevils present during the following season in the two localities. In May following the destruction of the plants careful search revealed only one weevil in the experimental area. In the check, however, the weevils were so numerous at this time that practically all of the squares had been destroyed. Examinations made later showed similar advantage in regard to freedom from the boll weevil of the area where the stalks were destroyed in October. The last examination was made on August 20. At this time there were 10 sound bolls to the plant on the experimental area and only 3 to the plant in the check area. The difference in yield between the two areas was about 600 pounds of seed cotton per acre. The work, therefore, resulted in an advantage amounting to about $18 per acre.

Newell and Dougherty[1] have described a very satisfactory device for cutting the cotton stalks in the fall. It consists of a triangular wooden framework, designed to pass between the rows and cut two at the same time. In the process of cutting, the machine windrows the stalks from two rows into the middle between the rows. The runners are provided with knives made of sharpened metal. Old saws have been found well adapted to the purpose. It is important to provide a metal runner at the rear end of the machine to prevent sliding. This runner is designed to run an inch or more beneath the surface of the ground. The device can be made by any blacksmith at a cost of about $4. It will cut and windrow from 10 to 15 acres of stalks in a day.

There is a disadvantage in cutting the stalks at or near the surface of the ground: If warm weather follows, many of the roots will give rise to sprouts that will furnish the weevils food. On this account the process is less effective than uprooting the plants. Wherever the stalk cutter is used, it should be followed by plows to remove the roots from the ground.

There is another important means by which the winter mortality of the weevil may be increased. This is by removing the hibernating quarters or destroying them after the weevil has gone into hibernation. Many of the insects are to be found in the winter in trash and débris found in and about cotton fields. The more shelter there is provided in the form of weeds growing about the fields, the more favorable the conditions will be for the insect. By the burning of such hibernating quarters as are found in the cotton fields and in their immediate vicinity a farmer can cut off a very large proportion of the weevils that would otherwise emerge to damage the crop.

The prolonged period of emergence from hibernation gives the planter another important advantage over the weevil. It has been shown on preceding pages that the period of emergence from hibernation extends, in normal seasons, to practically the 1st of July. In fact, except in one of the experiments that was performed, the last weevils did not appear until after the 20th of June. In the one exception the last weevils appeared on the 6th of June. In Texas it was found that 75 per cent of the emerging weevils appeared after

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[1] Cir. 30, Louisiana Crop Pest Commission.

April 8 and in Louisiana 64 per cent. In Texas, after May 1, in all the experiments, from 4 to 18 per cent of the surviving weevils appeared. In Louisiana, after May 1, from 30 to 40 per cent emerged. It is obvious that the fact that many weevils do not appear until long after cotton can be planted and brought to a fruiting stage is a very great advantage to the planter. A portion of a crop at least can be set before the weevils have become active. Usually it is possible to plant a crop sufficiently early to have it set some fruit before much more than 50 per cent of the surviving weevils have emerged.

Attention was directed to the fact that the development of the weevil is much slower in the early portion of the season than later. For instance, at Vicksburg, Miss., the average period of development in April is 30 days and in May 19 days. In June the period is shortened to 15 days. Consequently the planter has an opportunity to force the development of fruit on the plants when the weevils are being held in check by the temperatures of the spring months. The ability of the cotton plant to grow during April and May is much greater than that of the weevils. This gives a margin of which the planter can take advantage.

In the section dealing with natural control it was shown that climatic checks are the most important that the boll weevil experiences. The principal manner in which climatic factors affect the weevil is through the drying of the fruit. Naturally, the more heat and light there is to reach the fallen squares, the greater will be the effectiveness of the most important natural means of control. This is the basis for the recommendation that the plants should be given considerable space, not only between the rows, but in the drill. Of course, it would be possible to place the plants entirely too far apart, and thus reduce the yield. There is a happy medium, however, at which planters must arrive from experience on their individual places. At the same time, varieties should be cultivated which have a minimum tendency toward the formation of leafage.

The work of the insect enemies of the boll weevil is increasing from year to year. This work should be encouraged in so far as possible. It happens that several of the recommendations made for other reasons will result in facilitating the work of the enemies of the weevil. This is the case with early planting, wide spacing, and the use of varieties with sparse rather than dense leafage. Even fall destruction is not a disadvantage, because it forces the parasites at the active season to native hosts that carry them through the winter. Wherever possible, varieties should be planted which retain a large proportion of the infested squares, because the hanging squares are more favorable for parasite attack than those which fall.

Whenever the squares are picked by hand they should not be burned or buried, but placed in screened cages. In this way the weevils will be destroyed while the parasites may escape.

Numerous experiments have shown that a large proportion of the weevils buried under 2 inches of moist soil can not reach the surface. Unfortunately, it is not possible to plow the infested squares under 2 inches of soil during the growing season. The operation would result in injury to the root system and cause great shedding. Nevertheless it is possible for the planter to follow this practice after maximum infestation has been reached and after the plants have been uprooted. Therefore, every means should be taken at the time of maximum infestation to plow under the infested squares as deeply as possible. This method is of little use in dry regions, but fortunately is of great importance in humid regions where other means of control are comparatively lacking in efficiency. It is also assisted greatly by the occurrence of large areas of so-called stiff soils in the humid area.

SUMMARY OF MEANS OF REPRESSION OF THE BOLL WEEVIL.

In the preceding pages all effective methods of controlling the boll weevil have been described in a general way, and their connection with the life history of the insect shown. Further details regarding the application of the methods have been published in Farmers' Bulletin 344. In the present connection it will be sufficient to summarize the subject. The following are the essential features of the control of the boll weevil:

1. *Prevention of the invasion of new territory by means of quarantines directed against farm commodities that are likely to carry the weevil.* It is not necessary to have a quarantine applied to an extended list of articles. Only a few forms of cotton and of cotton by-products need to be considered. The most important is seed cotton. Next in importance are cottonseed and cottonseed hulls. There is no danger in cottonseed meal and scarcely any appreciable danger in baled cotton.

Cottonseed can be easily rendered entirely safe by fumigation with carbon bisulphid, as described in this bulletin.

2. *The destruction of the weevils in the fall by uprooting and burning or burying the plants.* This is by far the most important step in control. (See Pl. XX, *a*.) It is so important that unless it is followed all other means will avail little to the planter.

The burning of the cotton plants is, of course, a bad agricultural practice. It should not be followed except in extreme emergencies. In all other cases the plants should be uprooted as soon as the cotton can be picked and cut by means of stalk choppers and immediately plowed beneath the surface. The ground should afterwards be harrowed or dragged to make it still more difficult for the insects to emerge.

In many cases it will be found inadvisable to wait for the uprooting of the plants until all of the cotton is picked. After only a small portion remains for the pickers, it is entirely feasible to uproot the plants by means of a turning plow and leave them in the field so that the cotton can be picked. This will hasten the opening of the green bolls and frequently result in a considerable saving to the planter.

3. *The destruction of the weevils during the winter.* This is accomplished by the destruction of the places in which the insects hibernate. Many such places are found in the cotton fields or in their immediate vicinity. A certain number of the weevils will of course make their way into the heavy woods and other situations beyond the reach of of the planter, but many remain where they can be reached.

4. *Obtaining an early crop.* (See Pl. XXII.) The importance of obtaining an early crop has been shown to depend upon the small number of weevils which hibernate successfully, their late emergence from hibernating quarters, and their comparatively slow development

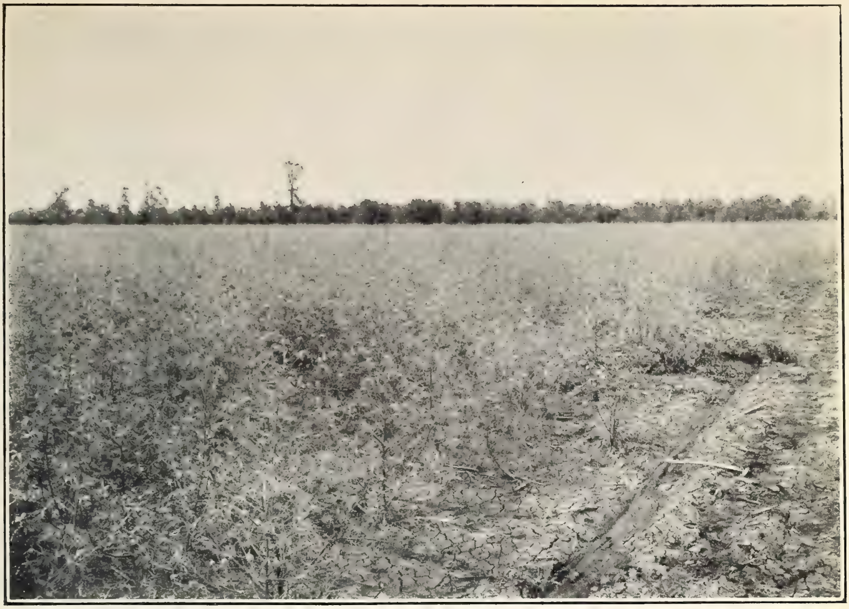

Fig. a.—Late-planted cotton under boll-weevil conditions, given same culture as early planting. (Original.)

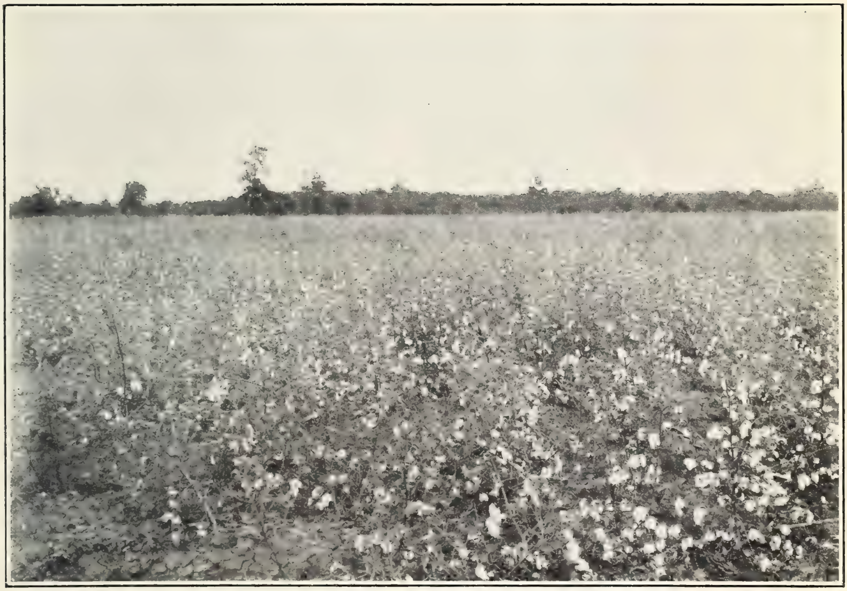

Fig. b.—Early-planted cotton adjoining the late planting under same conditions. (Original.)

RESULTS OF EARLY AND LATE PLANTING OF COTTON.

during the early part of the season. The obtaining of an early crop is brought about by early preparation of the soil, by early planting, by the use of early-maturing varieties, by a system of fertilization which will stimulate the growth of the plants, and by continuous shallow cultivation during the season.

5. *Increasing the effects of climatic control.* As has been shown, practically 50 per cent of all the weevil stages throughout the infested territory are destroyed by climatic influences. This means that the power of reproduction of the weevils is reduced by one-half. A planter can increase the advantage in his favor by providing a suitable distance between the plants and between the rows. It is also important to use varieties, where possible, which have a comparatively small leaf area. The use of the chain cultivator will be found of great value in connection with obtaining the full effects of climatic control.

6. *Encouraging the insect enemies of the weevil.* This is accomplished in part by procedures already recommended and further by the use of varieties which have a well-developed tendency to retain the fruit and which also have a comparatively open structure and small leafage.

7. *Hand picking of weevils and squares.* This is a practice of little general importance. Although under some local conditions it may be highly advisable, everything depends upon the cheapness with which the work can be done. On crops produced by wage hands it is doubtful if the hand picking of the weevils or squares will ever result in any profit. Where the crop is produced on the share basis, and the acreage is sufficiently small to allow considerable work in the picking of the squares, the practice will undoubtedly pay. It is, therefore, a matter that must be taken into consideration by each individual planter. It can not be recommended generally, for the reason that under many conditions it would result in loss.

Wherever square picking is practiced the squares should not be burned. They should be placed in cages, so that the parasites may escape and continue their work. As a matter of fact, under most conditions it is likely that the encouragement that can be given the parasites by this means is of much more importance than any direct checking of the weevil by the process of hand picking. Wherever squares are burned the planter is merely destroying the enemies of the weevil and consequently working against his own interest.

8. *Control at gins.*—The use of modern cleaner feeders will eliminate practically all of the weevils from cottonseed. Such devices should be used at least in the case of all seed that is intended for shipment into any infested localities and especially along the outer border of the infested territory, where wagons may carry infested cottonseed some distance into territory that has not been reached by the weevil. It is important in connection with the cleaner feeders to provide some means for the destruction of the insects that are captured. In some cases where the cleaner feeders are in operation the discharge is allowed to accumulate in an open barrel or box. From such receptacles weevils readily make their way into the seed cotton in storage. It is a simple matter to provide compression rollers through which the discharge from the cleaner feeder is passed. If, for any reason, the use of compression rollers is impracticable, the trash should be

fumigated at frequent intervals by means of carbon bisulphid or collected in a closed chamber and burned before the weevils have an opportunity to escape. (See Pl. X, *a*.)

9. *Fumigation of seed* (fig. 34). This is a means of repression that will be of avail only in the case of shipments of seed into uninfested territory. It has been found that carbon bisulphid is the most satisfactory agent to use. Great care should be taken to insure thoroughness of application.

The use of a crossbar attached to the cultivator to jar the infested squares from the plants has frequently been recommended. Under some conditions this practice should be followed, but under others it is worse than futile. It was shown, in the treatment of the subject of natural control of the weevil, that in the humid region, including Arkansas, Louisiana, and the eastern portion of Texas, the mortality in hanging squares is greater than in fallen squares. For this reason it is better for the squares to remain on the plants. There is another reason why they should be allowed to remain on the plants which applies especially to the moist region in which the boll weevil is now doing great damage. This is, that the hanging squares are much preferred by the boll-weevil parasites. The records have invariably shown a higher rate of parasitism in hanging squares than in fallen squares. In this way the hanging squares furnish a means for the breeding of parasites, thereby enabling them to establish themselves in the field.

It will be noted that the means of repression of the boll weevil may be divided into two classes, namely, direct and indirect.

The direct means of control are the destruction of the weevils in the fall by destroying the plants and burning or burying the immature stages, hand picking of weevils and squares under some conditions, the burial of the infested forms at the time of maximum infestation, and the burning of the hibernating weevils in their winter quarters.

The indirect means of control are early planting, the use of early varieties and of fertilizers that will accelerate growth, the selection of fields where the soil is suitable to rapid development, frequent shallow cultivation, the encouragement of the parasites of the weevil by placing the infested squares that may be picked by hand in cages instead of burning them, and the use of machinery which facilitates the various operations in preparing the land and cultivating the crop. These have the effect of increasing the acreage that a hand may cultivate. In view of the fact that the boll weevil forces a reduction in the acreage per hand, this is a consideration of some moment.

DESTROYING THE BOLL WEEVIL IN COTTON SEED.

It has been shown in this bulletin that adult weevils are frequently to be found in cotton seed and that there is danger in the dissemination of the pest through the shipment of the seed. A number of experiments have been performed to discover means of killing the weevils found in seed. There are great difficulties to be overcome on account of the density of the seed and its practical impenetrability by certain fumigants. It was shown, for instance, that hydrocyanic-acid gas has practically no penetrating power whatever. Carbon bisulphid was found to be satisfactory, although a special apparatus and special manipulation of the seed are necessary to insure success. The method described below, from Farmers' Bulletin 209, is that which has been used by the bureau in cases where it has been necessary to free cotton seed of the weevils.

The following plan for this work is proposed: A tight matched-board box should be provided having sides 4 feet high, open on top, and of other dimensions to accommodate 12 or more 100-pound sacks of cotton seed placed upright upon the bottom. Another tier of sacks could be added if desired. Into each one of these sacks about 1 ounce of carbon bisulphid should be forced by an apparatus for volatilizing the liquid and mixing the vapor with air. The accompanying illustration (fig. 34) will give an idea of this apparatus. It should consist of three essential parts, as shown in the illustration. *A* is an air pump having sufficient storage capacity to enable it to maintain a steady discharge of air for several minutes without continuous pumping. The stopcock at a_1 regulates or prevents the escape of air, as may be desired. *B* is an ordinary 2-quart bottle fitted at b^1 with a tight stopper of good length, having two openings, through which the inlet and outlet pipes pass. These pipes may be of glass or metal and should be as large as can be used. The inlet pipe, b_2, reaches nearly to the bottom of the bottle and is provided at the lower end with a perforated metal cap as large as will pass through the neck of the bottle. This allows the escape of the air in small bubbles and insures rapid evaporation. The outlet pipe, b_4, reaches only through the stopper. Upon the outside of the bottle is pasted a paper marked with 1-ounce graduations. *C* is a piece of ordinary ⅜-inch iron gas pipe about 3½ feet long, but this may be any desired length. It is closed and roundly pointed at the tip, and for about 15 to 18 inches of its length provided with small perforations pointing in all directions to give free escape to the vapor into all parts of the sack of seed at once.

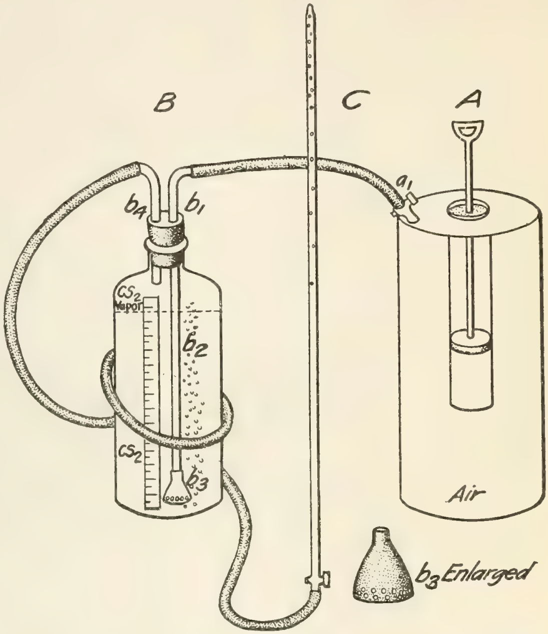

FIG. 34.—Apparatus for fumigating cotton seed in the sack. (After Hunter.)

The connections may be of rubber tubing, but as little rubber as possible should be used for this apparatus, as it is affected by the vapor of the bisulphid, and the couplings will have to be frequently replaced. This, however, will not be a considerable item of expense. With the apparatus just described one operator would be able to accomplish the entire work of disinfection. The amount of carbon bisulphid recommended is about 1 ounce for each 3-bushel sack. It is safe to say that this can be secured for less than 1 cent per ounce when purchased in 25 or 50 pound lots, making the cost of bisulphid not over 1 cent per sack. As it requires but from two to three minutes to vaporize 1 ounce of the liquid in the manner described, the expense for labor in application would not amount to one-half a cent per sack. Fumigation with carbon bisulphid can therefore be effectively made at the slight expense of from 1 to 1½ cents per 100-pound sack.

Application of the bisulphid in this manner reduces the elements of danger to a minimum, as the vapor is almost wholly confined and the slight quantity escaping, mixed with the open air, would not be in either inflammable or explosive proportions. It has been determined that the slight trace of bisulphid vapor in the air would not injure the operator in the slightest degree. The sacks should be left in the box for forty hours after the gas is injected.

LEGAL RESTRICTIONS REGARDING THE BOLL WEEVIL.

UNITED STATES STATUTE.

The statute, quoted in part below, prohibits the interstate shipment of the boll weevil and certain other insects, and provides penalties:

AN ACT To prohibit the importation or interstate transportation of insect pests, and the use of the United States mails for that purpose.

That no railroad, steamboat, express, stage, or other transportation company shall knowingly transport from one State or Territory into any other State or Territory, or from the District of Columbia into a State or Territory, or from a State or Territory into the District of Columbia, or from a foreign country into the United States, the * * * boll weevil, in a live state, or other insect in a live state which is notoriously injurious to cultivated crops; * * * or the eggs, pupæ or larvæ of any insect injurious as aforesaid, except when shipped for scientific purposes under the regulations hereinafter provided for, nor shall any person remove from one State or Territory into another State or Territory, or from a foreign country into the United States, or from a State or Territory into the District of Columbia, or from the District of Columbia into any State or Territory, except for scientific purposes under the regulations hereinafter provided for, the * * * boll weevil, * * * in a live state, or other insect in a live state which is notoriously injurious to cultivated crops; * * * or the eggs, pupæ or larvæ of any insect injurious as aforesaid. (33 Stat. L., 1269.)

Sec. 2. That any letter, parcel, box, or other package containing the * * * boll weevil * * * in a live state or other insect in a live state which is notoriously injurious to cultivated crops; * * * or any letter, parcel, box, or package which contains the eggs, pupæ or larvæ of any insect injurious as aforesaid, whether sealed as first class matter or not, is hereby declared to be nonmailable matter, except when mailed for scientific purposes under the regulations hereinafter provided for, and shall not be conveyed in the mails, nor delivered from any post office, nor by any letter carrier, except when mailed for scientific purposes under the regulations hereinafter provided for; and any person who shall knowingly deposit, or cause to be deposited, for mailing or delivery, anything declared by this section to be nonmailable matter, or cause to be taken from the mails for the purpose of retaining, circulating, or disposing of, or of aiding in the retention, circulation or disposition of the same shall, for each and every offense, be fined, upon conviction thereof, not more than five thousand dollars or imprisoned at hard labor not more than five years, or both, at the discretion of the court: *Provided*, That nothing in this Act shall authorize any person to open any letter or sealed matter of the first class not addressed to himself. (33 Stat. L., 1270.)

Sec. 3. That it shall be the duty of the Secretary of Agriculture and he is hereby authorized and directed to prepare and promulgate rules and regulations under which the insects covered by sections one and two of this Act may be mailed, shipped, transported, delivered and removed, for scientific purposes, from one State or Territory into another State or Territory, or from the District of Columbia into a State or Territory, or from a State or Territory into the District of Columbia, and any insects covered by sections one and two of this Act may be so mailed, shipped, transported, delivered and removed, for scientific purposes, under the rules and regulations of the Secretary of Agriculture: *Provided*, That the rules and regulations of the Secretary of Agriculture, in so far as they affect the method of mailing insects, shall be approved by the Postmaster-General, and nothing in this Act shall be construed to prevent any State from making and enforcing laws in furtherance of the purposes of this Act, prohibiting or regulating the admission into that State of insects from a foreign country. (33 Stat. L., 1270.)

Sec. 4. That any person, company, or corporation who shall knowingly violate the provisions of section one of this Act shall, for each offense, be fined, upon conviction thereof, not more than five thousand dollars or imprisoned at hard labor not more than five years, or both, at the discretion of the court. (33 Stat. L., 1270.)

QUARANTINES OF THE SEVERAL STATES.

Quarantines designed to prevent the importation of the boll weevil are now in force in the following States and Territories: Alabama, California, Georgia, Louisiana, Mississippi, North Carolina, Oklahoma, Porto Rico, South Carolina, Tennessee, and Texas. They are directed against all infested counties and States, as well as against all counties which may become infested in the future. The following pages give the substance of the present restrictions. For further particulars the quarantine officers of the several States should be addressed directly.

Alabama.—The present quarantine regulations in Alabama were promulgated by the Alabama State board of horticulture on April 4, 1911. The quarantine applies to cotton seed, seed cotton, hulls, seed-cotton and cottonseed sacks (which had been used), cotton-pickers' sacks, and corn in the shuck. Importation of these articles into uninfested territory from infested territory, or from any point situated within 20 miles of the area known to be infested, is prohibited. However, between January 15 and July 15 shipments of these articles originating within or ginned within a zone 20 miles in length immediately adjoining the infested territory may be made to points not more than 40 miles outside of the line of infestation. Between October 1 and June 30 shipments of Spanish moss, baled or unbaled, originating in infested territory, are prohibited from entering or passing through uninfested parts of the State. Cotton lint (loose, baled, flat, or compressed) originating in infested localities is prohibited except during the months of June, July, and August. The shipment of household goods is prohibited unless accompanied by an affidavit attached to the waybill to the effect that the shipment contains no cotton, cotton seed, seed cotton, hulls, seed-cotton and cottonseed sacks, cotton-pickers' sacks, corn in the shuck, or loose Spanish moss, except that in shipments of household goods made during the months of July, August, and September corn shucks or Spanish moss may be used for packing. All shipments of quarantined articles must be made in tightly closed box cars. No person except the entomologist of the State board of horticulture and his deputies is allowed to have in possession outside of the weevil-infested territory any live stages of the boll weevil. The penalty provided is a fine of from $100 to $500.

California.—In California the boll-weevil quarantine is in the form of an order issued by the State commissioner of agriculture on April 23, 1908. This provides that all cotton seed shipped into California shall be consigned through one of the State deputy commissioners of horticulture. These shipments shall be fumigated with carbon bisulphid for a period of 24 hours by a deputy commissioner. Deputy commissioners are located at El Centro, San Bernardino, Riverside, Los Angeles, and San Diego.

Florida.—The restrictions in effect are authorized by a statute passed in 1911 which established the office of inspector of nursery stock. Dr. E. W. Berger, Gainesville, is the present inspector.

Georgia.—Previous to August 15, 1904, the Georgia State board of entomology had authority, by virtue of the legislative act which created it, to enact such regulations as it deemed necessary to prevent the introduction or dissemination of injurious crop pests or diseases. On August 28, 1903, this board adopted a regulation prohibiting the introduction of cotton seed from Texas except under a certificate from an authorized State or Government entomologist stating that the seed had been fumigated in such manner as to kill any stage of boll weevils which might be contained therein. On

August 15, 1904, an act of the General Assembly of the State of Georgia was approved, but further amended August 23, 1905, whereby cotton seed, seed cotton, cottonseed hulls, or cotton lint in bales or loose, corn in the husk, or all material, including household goods packed in any of the above quarantined products, are prohibited from being brought into the State except when there is attached thereto a certificate signed by an authorized State or Government entomologist to the effect that said material was grown in and was shipped from a point where, by actual inspection, the Mexican cotton-boll weevil was not found to exist. Through shipments of quarantined articles may be made in cars which must be tightly closed, and no unloading is allowed during transit through the State. No common carrier shall use for bedding or feed for live stock any of the quarantined articles when the shipments originate in regions infested with the boll weevil.

Mr. E. L. Worsham, capitol, Atlanta, is the present quarantine official in Georgia.

Louisiana.—The State entomologist of Louisiana is, by a law passed December 15, 1903, empowered to quarantine against the cotton-boll weevil whenever it seems advisable. At present the State is entirely infested, but if in the future portions of the State should be freed the entomologist is fully empowered to restrict dangerous shipments into such portions.

Mr. J. B. Garrett, Baton Rouge, La., is the quarantine officer of this State.

Mississippi.—The State legislature in 1908 passed a law giving the entomologist of the experiment station considerable authority in regard to the quarantines against the boll weevil. As only part of the State is infested, and it may be possible to save certain portions several years of injury, the rules established in 1904 should be considered in force as restricting shipments into uninfested counties. An absolute quarantine is established against cotton seed, seed cotton, hulls, seed-cotton and cottonseed sacks (which have been used), cotton-pickers' sacks, corn in the shuck, unsacked corn, unsacked oats, unsacked wheat, and unsacked cowpeas from the infested territory. Through shipments of quarantined articles must be in tightly closed cars, which must not be unloaded while in transit through the State. Household goods to be shipped from infested territory into uninfested parts of the State of Mississippi must be accompanied by an affidavit to the effect that no quarantined articles are contained as packing or otherwise in the shipment. Baled cotton can be shipped into the uninfested parts of the State only in tightly closed cars.

Prof. R. W. Harned, Agricultural College, Miss., is the quarantine officer of this State.

North Carolina.—By virtue of authority from the State legislature to prevent the importation of crop pests, the North Carolina Crop Pest Commission early in 1904 adopted rules establishing a quarantine against all localities where the Mexican cotton-boll weevil is known to exist. The quarantine was absolute and applied to cotton, cotton seed, cottonseed meal, cottonseed hulls, hay, oats, corn, rice, straw, rice chaff, and other grain or material likely to harbor any stage of the boll weevil.

The rules published in July, 1910, are reproduced verbatim:

Regulation No. 15. No transportation company, common carrier, or agent thereof, shall bring into North Carolina any shipment of seed cotton or cotton-seed hulls originating at any point in the States of Texas, Louisiana, Mississippi, Oklahoma and Alabama. And this shall likewise apply to other States when the boll weevil shall be determined to be established within their borders.

Regulation No. 16. Shipments of cotton destined to any points in North Carolina and which originate at any point within the States of Texas, Louisiana, Mississippi, Oklahoma, Arkansas and Alabama, or other States that may hereafter become infested with cotton boll weevil, shall only be in hard compressed bales. If shipped in any other form, it is declared to be a public nuisance and is liable to seizure by the Board of Agriculture or its agents.

Regulation No. 17. Any shipment of cotton seed which originates at any point in Texas, Louisiana, Mississippi, Oklahoma, Arkansas or Alabama, and which is destined to any point in North Carolina, can be accepted for transportation only if it shall have attached to the bill of lading a certificate or statement signed by a duly authorized State or Government Entomologist stating that the point from which said shipment originates is a locality not known to be in the area of the boll weevil infection.

Regulation No. 18. If any shipment of seed cotton, cotton-seed hulls, cotton, or cotton seed not in accordance with these regulations be presented to any transportation company, common carrier, or agent thereof, for shipment to or delivery at any point within this State, same shall be refused, and the case shall be reported to the North Carolina State Department of Agriculture, at Raleigh, giving the name and address of the consignor and of the consignee.

Prof. Franklin Sherman, jr., Raleigh, N. C., is the quarantine officer in this State.

Oklahoma.—By virtue of rules and regulations issued by the State entomologist in accordance with the laws of the State, shipments of cotton seed, cottonseed hulls, seed-cotton and cottonseed sacks, cotton-pickers' sacks, and corn in the shuck are prohibited from infested territory into uninfested territory. In the same manner household goods are prohibited unless accompanied by a certificate that no quarantined material is contained therein. Through shipments of quarantined articles shall be made in tightly closed box cars and shall not be unloaded while in transit through the State. Shipments of baled cotton into uninfested parts shall be made in tightly closed box cars. No common carrier shall use for bedding or feed for live stock any of the quarantined articles which may have originated in infested territory. All persons are expressly forbidden to send live weevils in any stage to any point in or outside of the State, either by mail, express, or otherwise.

Prof. C. E. Sanborn, Stillwater, Okla., is the quarantine agent for this State.

Porto Rico.—By legislative act no cotton seed, seed cotton, cotton lint, loose or in bales, shall be brought into the island of Porto Rico, from any State or county whatsoever without being accompanied by the certificate of a duly authorized State or Federal entomologist that the shipment originated in a locality where, by actual inspection of such official or his agent, the boll weevil was not found to exist. Shipments not so certified are liable to seizure and destruction. Punishment is provided for in section 16 of the Penal Code of Porto Rico of 1902.

The governor of the island has direct control over the enforcement of this law.

South Carolina.—In South Carolina the quarantine regulations are entirely embodied in the laws of the State, and consequently not so readily modified to conform with the changed conditions and a better understanding of the methods of dissemination of the boll weevil as is the case when authority to promulgate rules and regulations is invested in a commission or in the State entomologist. The law established to guard against the introduction of the Mexican boll weevil into the State of South Carolina was approved on February 25, 1904. The commodities quarantined against were cotton seed, oats, and prairie hay, shipped directly or indirectly from infested points in the State of Texas.

Prof. A. F. Conradi, Clemson College, S. C., can furnish information concerning the interpretation of the State law.

Tennessee.—In compliance with the requirements of an act of the General Assembly of the State of Tennessee (S. B. No. 442, chap. 466), approved April 17, 1905, entitled "An act to create a State entomologist and plant pathologist," etc., the State board of entomology, established by said act, announced the following rules and regulations under date of December 31, 1910.

> (*a*) No cotton lint (loose, baled, flat, or compressed), cotton seed, seed cotton, cotton-seed hulls, seed-cotton or cotton-seed sacks (which have been used), or corn in the shuck, shall be shipped into Tennessee from the infested territory of Texas, Oklahoma, Louisiana, Arkansas and Mississippi.
>
> (*b*) Shipments of household goods from infested areas of above named States shall not be admitted into Tennessee unless accompanied by an affidavit attached to the way-bill to the effect that the shipment contains no cotton lint, cotton seed, seed cotton, cotton-seed hulls, seed-cotton or cotton-seed sacks, or corn in the shuck.
>
> (*c*) It shall be unlawful for anyone in Tennessee to have in his possession live Mexican cotton boll weevils. The public is urged to recognize the danger of introducing unwittingly live boll weevils for inspection, observation, or experiment.

Mr. G. M. Bentley, Knoxville, Tenn., is the officer in this State.

Texas.—In accordance with an act of the State legislature, to prevent the spread and dissemination of injurious insects, the commissioner of agriculture designated the boll weevil as such an insect to be quarantined. This ruling in the act makes it illegal to ship seed cotton or cotton seed, or any other article which might carry the boll weevil from an infested county to an uninfested county.

Mr. Ed. R. Kone, Austin, Tex., is the State officer charged with quarantine enforcement.

Regulations of foreign governments.—The Governments of Egypt, Peru, and India have established an injunction against the importation of American cotton seed originating in the infested localities. In all cases, however, it can be arranged to have shipments cleared in case they are accompanied by certificates of fumigation by a competent authority.

BIBLIOGRAPHY.

This bibliography includes only the more important writings which have been published in permanent form. In the preliminary part of this bibliography a special synopsis is given of the contents of publications, more particularly to outline the history of the cultural method now recognized as of supreme importance in the control of the boll weevil. No attempt is made to give a synopsis of the later titles. For a complete annotated bibliography see Circular No. 140, Bureau of Entomology.

1843. Boheman, C. H.—Genera et species Curculionidum cum synonymia hujus familiæ ed. C. J. Schönherr, vol. 5, pt. 2, pp. 232–233.

The original description of *Anthonomus grandis*.

1871. Suffrian, E.—Verzeichniss der von Dr. Gundlach auf der Insel Cuba gesammelten Rüsselkäfer.<Archiv f. Naturg., vol. 37, Jahrg. 13, pt. 1, pp. 130–131.

Contains the record of a specimen from Cardenas and one from San Cristobal, in Cuba.

1885. Riley, C. V.—Report of the Commissioner of Agriculture for 1885, p. 279.

Contains the sentence "Another very large species, *A. grandis* Boh., we have reared at this department from dwarfed cotton bolls sent from northern Mexico by Dr. Edward Palmer." This is the first published record of the food plant and method of injury of the species.

1891. Dietz, W. G.—Revision of the genera and species of Anthonomini inhabiting North America.<Trans. Amer. Ent. Soc., vol. 18, p. 205.

The species is here reported from Texas. It has been shown, however, that this was an error. (See Insect Life, vol. 7, p. 273.)

1891. Gundlach, Juan.—Contribucion á la entomologia Cubana, vol. 3, pt. 5, p. 285.

Mentions occurrence in Cuba.

1894. Howard, L. O.—A new cotton insect in Texas.<Ins. Life, vol. 7, p. 273.

The first authentic account of the occurrence of the species in the United States, and some statements regarding its life history.

1895. Howard, L. O.—The new cotton-boll weevil.<Ins. Life, vol. 7, p. 281.

1895. Townsend, C. H. T.—Report on the Mexican cotton boll weevil in Texas (*Anthonomus grandis* Boh.).<Ins. Life, vol. 7, no. 4, pp. 295–309, figs. 30, 31, March.

An important preliminary paper giving valuable data on life history and habits, an account of its spread from Mexico to Texas, and its extent in Texas at that time. In the consideration of remedies are suggested the cutting and burning over of the cotton fields in winter, the abandonment of cotton growing over the region then infested, and the maintenance of a wide zone free from cotton along the lower Rio Grande bordering Mexico, with other suggestions of less practical value.

1895. Howard, L. O.—The Mexican cotton-boll weevil.<Cir. 6 (second series), Div. Ent., U. S. Dept. Agr., pp. 5, figs. 1–3, April.

This circular gives the results, substantially, of Mr. Townsend's field investigations of the insect in Mexico and Texas. The impracticability of the use of poisons is shown, and the collection and destruction of infested bolls and rotation of crops are suggested. English and Spanish editions were issued.

1895. Rios, J. R.—Aparicion del "picudo" en la Laguna.<El Progreso de Mex., Aug. 15, 1895. Reprinted in vol. 4, pp. 811–813, 1897.

1896. Howard, L. O.—The Mexican cotton-boll weevil.<Cir 14 (second series), Div. Ent., U. S. Dept. Agr., pp. 8, figs. 1–5.

Contains a large amount of additional information relative to distribution, natural history and habits, and natural enemies and parasites, now worked out with substantial accuracy. Under the head of remedies is the first suggestion of the great importance of the cultural method of control, and especially the early fall destruction of the cotton plants, together with the recommendation of early planting and clean cultivation. Trapping late beetles in fall and over-wintered beetles in early spring is advised, together with the destruction of volunteer plants, the region infested up to this time being fairly within the range of volunteer or seppa cotton.

1897. Howard, L. O. The Mexican cotton-boll wevil.<Cir. 18 (second series), Div. Ent., U. S. Dept. Agr., pp. 8, figs. 1–5.

This circular brings the data on distribution and other features down to date, and in the matter of remedies incorporates the results of field studies in Texas by Mr. C. L. Marlatt on food habits and poisoning, and indicates the supreme importance of the cultural method of control, all other steps being merely palliative or to offset the failure to adopt this method. Issued in English, Spanish, and German editions.

1897. Junta de defensa contra el "picudo." (Editorial.)<El Progreso de Mex., vol. 5, pp. 8–9, Oct. 8.

1897. El picudo (*Anthonomus grandis* Boh.). (Editorial.)<Documentos referentes a su existencia en Mexico y a su invasion in los Estados Unidos del Norte. Mexico Oficina Tip. de la Secretaria de Fomento, pp. 100, figs. 1–5.

1897. Balestrier, L. de.—Las medias precautorias contra las plagas que asolan a la agricultura.<El Progreso de Mex., vol. 4, pp. 575–576, May 22.

1897. Howard, L. O.—The Mexican cotton-boll weevil in 1897. Cir. 27 (second series), Div. Ent., U. S. Dept. Agr., pp. 7.

This circular records more particularly the further spread of the weevil, and repeats the suggestions relative to the cultural method of control from Circular 18, which method is urged as a practically complete remedy for the insect.

1897. Howard, L. O.—Insects affecting the cotton plant.<Farm. Bull. 47, U. S. Dept. Agr., pp. 16–23, figs. 7–11.

Reprinted from Bulletin 33, Office of Experiment Stations, U. S. Dept. Agr., pp. 317-350.

1898. Howard, L. O.—Remedial work against the Mexican cotton-boll weevil.<Cir. 33 (second series), Div. Ent., U. S. Dept. Agr., pp. 6.

This is a supplementary circular giving the results of some experiments with poisons by Mr. Marlatt and Mr. Townsend. The cultural system of control is, however, again insisted upon.

1901. Rangel, A. F.—Estudios preliminares acerca del picudo del algodon (*Insanthonomus grandis* I. C. Cu.).<Boletin de la Comision de Parasitologia Agricola, vol. 1, no. 3, pp. 93–104, pl. 9 and figure.

Deals with 45 experiments regarding destruction by means of hot air, hot water, steam, haplaphyton, and arsenic.

1901. Mally, F. W.—A preliminary report of progress of an investigation concerning the life history, habits, injuries, and methods for destroying the Mexican cotton-boll weevil (*Anthonomous* (sic) *grandis*). Authorized by special Act of the Twenty-sixth Legislature of Texas, pp. 1–30, supplement pp. 35–45.

1901. Mally, F. W.—The Mexican cotton-boll weevil.<Farm. Bull. 130, U. S. Dept. Agr., pp. 30, figs. 1–4.

A reprint, with minor corrections, of the preceding, excepting the supplement. Contains much new valuable information, but in the subject of remedies represents Mr. Mally's own point of view and not the advice of the bureau current at the same time. Nevertheless, the cultural method is again given the greatest prominence.

1901. Rangel, A. F.—Segundo informe acerca del picudo del algodon (*Insanthonomus grandis* I. C. Cu.).<Boletin de la Comision de Parasitologia Agricola, vol. 1, no. 5, pp. 171–176.

1901. Rangel, A. F.—Tercer informe acerca del picudo del algodon.<Boletin de la Comision de Parasitologia Agricola, Mexico, vol. 1, no. 6, pp. 197–206.

1901. Rangel, A. F.—Cuarto informe acerca del picudo del algodon (*Insanthonomus grandis* I. C. Cu.).<Boletin de la Comision de Parasitologia Agricola, vol. 1, no. 7, pp. 245–261, pls. 16, 23.

1901. Rangel, A. F.—Quinto informe acerca del picudo del algodon.<Boletin de la Comision de Parasitologia Agricola, Mexico, vol. 1, no. 8, pp. 302–317.

1902. Ashmead, W. H.—A new Bruchophagus from Mexico.<Psyche, vol. 9, p. 324, March.

Contains the description of *Bruchophagus herreræ* n. sp., a parasite of *Anthonomus grandis*, from Coahuila, Mexico.

1902. Rangel, A. F.—Sexto informe acerca del picudo del algodon.<Boletin de la Comision de Parasitologia Agricola, Mexico, vol. 1, no. 9, pp. 403–407.

1902. Hunter, W. D.—The present status of the Mexican cotton boll weevil in the United States.<Yearbook U. S. Dept. Agr. for 1901, pp. 369–380, 1 fig.

In this publication the cultural method of control is substantially the only method recommended, augmented by the suggestion of securing northern seed and early maturing varieties to hasten the crop production; also suggests the wide spacing of rows to secure the same end.

1902. Mally, F. W.—Report on the boll weevil. Pp. 70, figs. 3. Austin, State Printer.

1902. Madero, J. M. C.—Una plaga del algodon.<Boletin de Agricultura. (Salvador) vol. 2, no. 14, pp. 483–485, July 15.

Comments on failure of means of control as then recommended by the United States Department of Agriculture. States that cotton growing has been abandoned on account of the weevil in Coahuila, for corn and wheat.

1903. Hunter, W. D.—Methods of controlling the boll weevil (advice based on the work of 1902).<Farm. Bul. 163, U. S. Dept. Agr., pp. 16, figs. 2, January.

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INDEX.

Acamatus commutatus. (See *Eciton* [*Acamatus*] *commutatus.*) Page.
Acorns attacked by *Balaninus nasicus* ... 30
Conotrachelus naso ... 30
of live oak attacked by *Balaninus victoriensis* ... 30
Agelaius phœniceus, enemy of boll weevil ... 146
Alabama argillacea (*see also* Leaf worm).
effect on boll-weevil dispersion ... 87
enemy of boll weevil ... 138–139
cotton ... 15
periodical abundance ... 83
Althæa sp. (*see also* Hollyhock).
tested as food plant of boll weevil ... 32
Altitude, effect on boll weevil ... 28–29
Amaranthus (*see also* Pigweed).
hybridus tested as food plant of boll weevil ... 32
spinosus tested as food plant of boll weevil ... 32
Ambrosia psilostachya tested as food plant of boll weevil ... 32
roots attacked by *Baris striata* ... 30
stems attacked by *Lixus scrobicollis* ... 30
Ant, Argentine. (See *Iridomyrmex humilis.*)
lion. (See *Dorymyrmex pyramicus.*)
Anthonomus albopilosus attacks seed pods of wild sage (Croton) ... 30
mistaken for boll weevil ... 30
eugenii attacks pepper pods ... 30
mistaken for boll weevil ... 30
fulvus attacks purple mallow buds ... 30
mistaken for boll weevil ... 30
grandis. (*See* Boll weevil.)
signatus attacks blackberry, dewberry, and strawberry buds ... 30
mistaken for boll weevil ... 30
vestitus attacks cotton squares in Peru ... 30
Anthribus cornutus attacks cotton stems ... 30
mistaken for boll weevil ... 30
Anthus pensilvanicus, enemy of boll weevil ... 146
Aphiochæta fasciata, enemy of boll weevil ... 142
nigriceps, enemy of boll weevil ... 142
pygmæa, enemy of boll weevil ... 142
Apiomerus spissipes, enemy of boll weevil ... 137
Aræcerus fasciculatus attacks china-berries, coffee beans, and old cotton bolls ... 30
breeds in old dried cotton bolls ... 30
mistaken for boll weevil ... 30
Arsenate of lead against boll weevil ... 150–151
Ashmouni. (*See* Cotton, Egyptian.)
Aspergillus, fungous enemy of boll weevil ... 136
Bæolophus atricristatus, enemy of boll weevil ... 146
bicolor, enemy of boll weevil ... 146
Balaninus nasicus attacks acorns ... 30
mistaken for boll weevil ... 30
victoriensis attacks live oak acorns ... 30
attraction to lights ... 154
mistaken for boll weevil ... 30, 154
Baptisia attacked by *Tychius sordidus* ... 30
Baris striata attacks roots of ragweed (Ambrosia) ... 30
mistaken for boll weevil ... 30
transversa attacks roots of cocklebur (Xanthium) ... 30
mistaken for boll wevil ... 30

Page.
Bark, hibernation shelter for boll weevil ... 101
Bartramia longicauda, enemy of boll weevil ... 146
Bermuda grass, duration of life of boll weevils fed thereon ... 48
Bindweed. (See *Convolvulus repens.*)
Birds inimical to boll weevil ... 145–146
Blackberry, host plant of *Anthonomus signatus* ... 30
Blackbird, Brewer. (See *Euphagus cyanocephalus.*)
    red-winged. (See *Agelaius phœniceus.*)
    rusty. (See *Euphagus carolinus.*)
Bloodweed, duration of life of boll weevils fed thereon ... 48
Blue jay. (See *Cyanocitta cristata.*)
Boll weevil, abundance, seasonal ... 74–85
        variations from year to year ... 83–85
    activity, zone of temperatures causing it ... 127
    adult, ability to locate cotton ... 41
        activity after emergence from hibernation ... 116–118
        attraction to various cottons ... 45–47
            substances ... 42–43
        changes after emergence ... 38
        color ... 36
        description ... 35
            of teneral stage ... 34–35
        destructive power by feeding ... 42
        duration of life according to sex ... 50
            average ... 47–50
            with normal food ... 49
            without normal food ... 48–49
        effects upon squares and bolls of feeding ... 44–45
        emergence ... 38
        feeding activity ... 41–42
            habits of hibernated weevils ... 41–42
        female, characters ... 37
        food habits ... 38–50
        habits, food ... 38–50
            protective ... 38
        longevity, maximum ... 115–116
            of those emerging from hibernation ... 114–116
        male, characters ... 37
        movements on food plant ... 43–44
        number on stalks at different dates ... 99
            under rubbish ... 99
        protective habits ... 38
        secondary sexual characters ... 37
        sense of color ... 43
        size ... 35–36
        weight ... 36
    æstivation, zone of temperatures causing it ... 127
    annual movement in square miles ... 27–28
    bibliography ... 169–175
    bird enemies ... 145–146
    breeding habit, the one probably original ... 62
    broods ... 74–76
    cannibalism ... 50
    causes for natural dissemination ... 87
    checked by altitude ... 28–29
        dryness ... 28
        low temperature ... 28
    climatic control, effect of cold ... 19
            drought ... 16
            early frost ... 20
        influences on vitality and activities ... 121–122
    compensations for losses caused thereby ... 26–27
    control by climatic conditions ... 120–132
        parasites ... 120
        predators ... 120
        proliferation ... 132–135

Page.

- Boll weevil, copulation, age at beginning 52
    - duration of act 52
- description 33–37
- development during winter 73–74
- diseases 136
- dispersion. (*See* Boll weevil, dissemination.)
- dissemination annually in square miles 27–28
    - artificial, intentional transportation 94
        - movement of baled cotton 93
            - cottonseed 92–93
            - farm hands 93–94
            - seed cotton 91–92
            - vehicles 93
    - as affected by leaf worm (*Alabama argillacea*) 87
    - natural, causes 87
        - fall dispersion 87–90
        - hibernation flight 90
        - other forms of natural spread 90–91
        - spring search for cotton 85–91
            - spread within the field 86
        - summer flights 86–87
- distribution 20–21
- effects thereon of flooding 131–132
- egg deposition. (*See* Boll weevil, oviposition.)
    - description 33
    - duration of stage 62–63
- eggs eaten by adult when laid outside 64
    - hatching 64
        - of those laid outside of cotton fruit 64
        - percentage 65
- fall dispersion 87–90
- fatalities from temperature variations 129–131
    - lower zone of temperatures causing it 128
    - upper zone of temperatures causing it 126
- faunal zone limits 29
- fecundity 60–61
- fertility, duration 52–53
- fertilization 52–53
- first account of damage 15
- food habits 38–50
    - plants 31–32
- generations 74–76
- hibernation 94–118
    - activity during period 103
    - emergence therefrom 107–110
        - activity of adults thereafter 116–118
        - longevity thereafter 114–116
        - rate 108–110
        - time 107–108
    - entrance 96–99
    - flight 90
    - length of period, average 103–105
        - extremes of variation 105
        - relation of shelter thereto 105–106
    - methods of study 95–96
    - number of adults entering 98–99
    - shelter 100–102
    - sources of weevils entering 96
    - stages entering 96–97
    - survival 110–114
        - influence of climate thereon 112–114
            - fall destruction of cotton stalks thereon 111–112
            - shelter thereon 112
    - time of entrance 97–98
    - zone of temperatures causing it 127–128

Page.
Boll weevil, history ... 15–20
    in Alabama ... 20
        Arkansas ... 20
        Costa Rica ... 20
        Cuba ... 16, 19, 21
        Florida ... 20
        Guatemala ... 18
        "Laguna" district of Mexico, discovery ... 18
        Louisiana ... 20
        Mexico ... 15, 16, 19, 20
        Mississippi ... 20
        Oklahoma ... 20
        Texas ... 20
    infestation, maximum, and its effect on multiplication ... 79–80
        progress, in fields ... 77–79
    insect control by months ... 144–145
            highest records ... 145
        enemies ... 136–145
    insects mistaken therefor ... 29–30
    intentional transportation ... 94
    invasion of Alabama ... 19
        Arkansas ... 19
        Florida ... 20
        Louisiana ... 18
        Mississippi ... 19
        Oklahoma ... 19
        Texas ... 16
    larva, description ... 33–34
        duration of stage ... 66
        food habits ... 65
        growth ... 65
        molts ... 66
    life cycle ... 69–74
        average duration ... 69
        in hanging squares ... 73
        variations due to location of developing stage ... 69
            sex ... 69
            temperature ... 70–72
            time of falling of infested squares ... 69–70
            in bolls ... 72
            miscellaneous ... 72–73
        history, summary ... 32–33
    losses due thereto ... 21–26
            compensation therefor ... 26–27
        indirect, due thereto ... 26
    mortality by sections ... 119–120
        due to heat and dryness ... 122–124
        in all classes of cotton forms ... 118–120
    natural control ... 118–146
            effect of defoliation of cotton ... 20
    origin ... 15–20
    oviposition, act ... 56–58
        activity at various times of day ... 58–59
        age at beginning ... 53–54
        dependence thereof upon food obtained from squares ... 55–56
        effects upon squares ... 61–62
        examination of squares before the act ... 54
        period ... 61
        place of egg deposition ... 56
        seasonal rate ... 59–60
        selection of squares ... 54–55
        stimulating effect of abundance of squares ... 58
        time required to deposit an egg ... 58
    parasite control by years ... 144
    parasites, rotation of hosts ... 143
    parthenogenesis ... 53

Page.

- Boll weevil, percentage developed from infested squares, 68
  - plant control, 132–136
    - by structural characteristics, 135–136
  - possible annual progeny, 76–77
  - prospects, 27–29
  - pupa, activity, 67
    - description, 34
    - duration of stage, 67–68
  - pupal cells, 67
  - pupation, 67
  - relation to top crop of cotton, 81–83
  - repression, 147–163
    - at gins, 152–153, 161–162
    - basis, 155–160
    - by arsenate of lead, 150–151
      - burial of squares, 147–149
      - chain cultivator, 151
      - destruction of cotton stalks, 160
        - weevils during winter, 160
      - early crop of cotton, 160–161
      - encouraging insect enemies, 161
      - fumigation of cotton seed, 162–163
      - hand-picking of weevils and squares, 161
      - increasing effects of climatic conditions, 161
      - insecticides, 149–151
      - legal restrictions, 164–168
      - machinery, 151–153
      - quarantine, 160
      - stalk destruction, 157–158
    - futile methods, 153–155
    - futility of attempting to restrict cotton production, 156–157
      - castor bean plant, 155
      - cottonseed oil, 153
      - mineral paint, 153
      - Paris green, 154
      - pepper plants, 155
      - spraying, 153
      - sulphur, 153
      - tobacco, 155
      - trapping at lights, 154
    - requirements of satisfactory method, 155
    - summary of means, 160–162
  - seasonal abundance, 74–85
  - sexes, seasonal proportion, 51–52
  - sex of hibernated boll weevils, 51–52
    - individuals ready to enter hibernation, 51
    - spring and summer boll weevils, 51
  - sexual attraction, 52
  - sporadic occurrences, unexplained, 94
  - spread. (*See* Boll weevil, dissemination.)
  - spring search for cotton, 85–86
    - spread within field, 86
  - status examinations, 80–81
  - summary of life history, 32–33
    - repressive measures, 160–162
  - summer flights, 86–87
  - temperature relationships, 125–131
    - variations fatal, 129–131
    - zones, 125–128
- Bollworm. (See *Heliothis obsoleta.*)
- *Bracon mellitor.* (See *Microbracon mellitor.*)
- *Bruchophagus herreræ*, enemy of boll weevil, 141
- Buildings as hibernation shelter for boll weevil, 102
- Bunting, painted. (See *Passerina ciris.*)
- Burial of squares, effect on boll weevil, 147–149

Page.

Callirhoe (*see also* Mallow).
  buds, duration of life of boll weevils fed thereon ... 48
  involucrata, tested as food plant of boll weevil ... 32
Cardinal. (See *Cardinalis cardinalis.*)
Cardinalis cardinalis, enemy of boll weevil ... 146
Careless weed. (*See* Euphorbia.)
Castor bean plants, futility against boll weevil ... 155
Cathartus gemellatus, enemy of boll weevil ... 138
Catolaccus hunteri, enemy of boll weevil ... 141
  incertus, enemy of boll weevil ... 141
Cerambycobius cushmani, enemy of boll weevil ... 141
  cyaniceps, enemy of boll weevil ... 141
  sp., enemy of boll weevil ... 141
Chain cultivator, use against boll weevil ... 151
Chalcodermus æneus attacks cowpea pods ... 30
  breeds in cotton squares ... 30
  mistaken for boll weevil ... 30
Chat, yellow-breasted. (See *Icteria virens.*)
Chauliognathus spp., enemies of boll weevil ... 137
Chickadee, Carolina. (See *Penthestes carolinensis.*)
China-berries attacked by *Aræcerus fasciculatus* ... 30
Chondestes grammacus, enemy of boll weevil ... 146
Chordeiles virginianus, enemy of boll weevil ... 146
Climate, factor in boll-weevil control ... 120–132
  mortality ... 120–132
Climatic conditions, factor in boll-weevil control ... 120–132
  influences on vitality and activities of boll weevil ... 121–122
Cocklebur. (*See* Xanthium.)
Coffee beans attacked by *Aræcerus fasciculatus* ... 30
  bean weevil. (See *Aræcerus fasciculatus.*)
Cold, effect on boll weevil ... 19, 28
Colinus virginianus, enemy of boll weevil ... 146
Colors, attractiveness to boll weevil ... 43
Conotrachelus elegans attacks galls and nuts of pecan ... 30
    mistaken for boll weevil ... 30
  erinaceus mistaken for boll weevil ... 30
  leucophæatus attacks stems of careless weed (Euphorbia) ... 30
    mistaken for boll weevil ... 30
  naso attacks acorns ... 30
    mistaken for boll weevil ... 30
  nenuphar (*see also* Plum curculio).
    attacks fruit of plums and peaches ... 30
    mistaken for boll weevil ... 30
Convolvulus repens tested as food plant of boll weevil ... 32
Cordyceps, fungous enemy of boll weevil ... 136
Corn, duration of life of boll weevils fed thereon ... 48
Cornstalks, hibernation shelter for boll weevil ... 101
Cotton, American Upland, susceptibility to boll-weevil attack ... 45, 46
  baled, factor in dissemination of boll weevil ... 93
  bolls, duration of life of boll weevils fed thereon ... 49
    effect of feeding by boll weevil thereon ... 45
    old, attacked by *Aræcerus fasciculatus* ... 30
    pendent, indirect effect on boll weevil ... 135
    with thick walls, effect on boll weevil ... 136
  boll weevil. (*See* Boll weevil.)
  caterpillar. (See *Alabama argillacea* and Leaf worm.)
  Cuban, susceptibility to boll-weevil attack ... 45, 46
  destruction of stalks as a means of boll-weevil repression ... 157–158
  determinate growth, effect on boll weevil ... 135
  early bearing, effect on boll weevil ... 135
    maturing varieties as a means of boll-weevil repression ... 160–161
    planting as a means of boll-weevil repression ... 160–161
  Egyptian, susceptibility to boll-weevil attack ... 45, 46
  fall destruction of stalks in relation to survival of boll weevil from hibernation ... 111–112
  fertilization as an aid to boll-weevil repression ... 160–161
  flowers attacked by *Echthetopyga gossypii* in Philippines ... 30

Page.
Cotton, foliage, duration of life of boll weevils fed thereon 49
food plant of *Alabama argillacea* 15
Anthonomus grandis 1–175
vestitus 30
Anthribus cornutus 30
Chalcodermus æneus 30
Echthetopyga gossypii 30
Heliothis obsoleta 15
hairy stalks, effect on boll weevil 135
involucral bracts, effect on boll weevil 136
"kidney," host plant of boll weevil in Cuba 16, 31
"loose." (See *Gossypium brasiliense.*)
nectar, indirect effect on boll weevil 135
visited by *Geræus penicellus* 30
picumnus 30
picking of squares as a means of boll-weevil repression 161
planting early as a means of boll-weevil repression 160–161
restriction an impracticable means of boll-weevil repression 156–157
time, effect on longevity of boll weevils 116
plant, proliferation, effect on boll weevil 132–135
structures inimical to boll weevil 135–136
retention of fruit, effect on boll weevil 136
Sea Island, susceptibility to boll-weevil attack 45, 46
seed, factor in dissemination of boll weevil 92–93
shallow cultivation as a means of boll-weevil repression 160–161
squares attacked by *Anthonomus vestitus* in Peru 30
Chalcodermus æneus 31
burial, effect on boll weevil 147–149
duration of life of boll weevils fed thereon 49
effect of feeding of boll weevil thereon 44–45
picking, as a means of boll-weevil repression 161
square weevil, Peruvian. (See *Anthonomus vestitus.*)
stalks as hibernation shelter for boll weevil 100
destruction in fall as a means of boll-weevil repression 111–112
stems attacked by *Anthribus cornutus* 30
top crop as affected by boll weevil 81–83
tree, host plant of boll weevil 31
"wild." (See *Gossypium brasiliense.*)
Cottonseed meal, nonattractiveness to boll weevil 42
oil as bait against boll weevil, futility 153
Cottonwood catkins attacked by *Dorytomus mucidus* 30
Cowbird. (See *Molothrus ater.*)
Cowpea curculio (see also *Chalcodermus æneus*).
host of *Ennyomma globosa* 142
food plant of *Chalcodermus æneus* 30
pod weevil. (*See* Cowpea curculio and *Chalcodermus æneus.*)
Cremastogaster lineolata læviuscula clara, enemy of boll weevil 139
Croton, host plant of *Anthonomus albopilosus* 30
Cyanocitta cristata, enemy of boll weevil 146
Dendroica æstiva, enemy of boll weevil 146
coronata, enemy of boll weevil 146
Desmoris constrictus attacks seed of sunflower (Helianthus) 30
mistaken for boll weevil 30
scapalis attacks flower heads of broad-leaved gum plant (Sideranthus) 30
mistaken for boll weevil 30
Dewberry, host plant of *Anthonomus signatus* 30
Dickcissel. (See *Spiza americana.*)
Dorymyrmex pyramicus, enemy of boll weevil 140
flavus, enemy of boll weevil 140
Dorytomus mucidus attacks cottonwood catkins 30
mistaken for boll weevil 30
Drought, effect on boll weevil 16
Dryness, effect on boll weevil 28
factor in boll-weevil mortality 122–124
Eciton (Acamatus) commutatus, enemy of boll weevil 139
Ectatomma tuberculatum, enemy of boll weevil 139
Ecthetopyga gossypii feeds in cotton flowers in Philippines 30

Page.

Empidonax minimus, enemy of boll weevil ... 146
traillí alnorum, enemy of boll weevil ... 146
Ennyomma globosa, enemy of boll weevil ... 142
cowpea curculio (*Chalcodermus æneus*) ... 142
Epicærus imbricatus mistaken for boll weevil ... 30
Euphagus carolinus, enemy of boll weevil ... 146
cyanocephalus, enemy of boll weevil ... 146
Euphorbia stems attacked by *Conotrachelus leucophæatus* ... 30
Eurytoma sp., enemy of boll weevil ... 141
tylodermatis, artificial increase of effectiveness as boll-weevil parasite ... 143
enemy of boll weevil ... 141
Evarthrus sodalis, enemy of boll weevil ... 137
sp., enemy of boll weevil ... 137
Excelsior, duration of life of hibernated boll weevils fed thereon ... 48
False indigo. (*See* Baptisia.)
Farm hands, movement, factors in dissemination of boll weevil ... 93–94
Faunal zone limitations upon boll weevil ... 29
Flooding, effects upon boll weevil ... 131–132
Flycatcher, alder. (See *Empidonax trailli alnorum*.)
crested. (See *Myiarchus crinitus*.)
least. (See *Empidonax minimus*.)
olive-sided. (See *Nuttallornis borealis*.)
scissor-tailed. (See *Muscivora forficata*.)
Forelius maccooki, enemy of boll weevil ... 140
Formica pallidifulva, enemy of boll weevil ... 140
subpolita perpilosa, enemy of boll weevil ... 140
Geothlypis trichas, enemy of boll weevil ... 146
Geræus penicellus mistaken for boll weevil ... 30
visits cotton nectar ... 30
picumnus mistaken for boll weevil ... 30
visits cotton nectar ... 30
Gerstæckeria nobilis attacks joints of prickly pear ... 30
mistaken for boll weevil ... 30
Ginning machinery used in repression of boll weevil ... 152–153
Gossypium (*see also* Cotton).
brasiliense, food plant of boll weevil ... 16, 31
Grackle, bronzed. (See *Quiscalus q. æneus*.)
great-tailed. (See *Megaquiscalus major macrourus*.)
Guatemalan ant. (See *Ectatomma tuberculatum*.)
Gum plant, broad-leaved. (*See* Sideranthus.)
Habrocytus piercei, enemy of boll weevil ... 141
Hay, duration of life of boll weevils fed thereon ... 48
Heat, factor in boll-weevil mortality ... 122–124
Helianthus (*see also* Sunflower).
annuus, tested as food plant of boll weevil ... 32
seed attacked by *Desmoris constrictus* ... 30
Heliothis obsoleta an enemy of cotton ... 15
Hibiscus africanus, buds, duration of life of boll weevils fed thereon ... 48
tested as food plant of boll weevil ... 31, 32
buds, Japanese, duration of life of boll weevils fed thereon ... 48
esculentus tested as food plant of boll weevil ... 31
leaf, duration of life of boll weevils fed thereon ... 48
manihot tested as food plant of boll weevil ... 31
militaris, buds, duration of life of boll weevils fed thereon ... 48
tested as food plant of boll weevil ... 31, 32
moscheutos, buds, duration of life of boll weevils fed thereon ... 48
tested as food plant of boll weevil ... 31, 32
vesicarius tested as food plant of boll weevil ... 31, 32
Hirundo erythrogastra, enemy of boll weevil ... 146
Hollyhock (see also *Althæa* sp.).
buds, duration of life of boll weevils fed thereon ... 48
Honey, attractiveness to boll weevil ... 43
Hydnocera pallipennis, enemy of boll weevil ... 138
pubescens, enemy of boll weevil ... 138
Hylobius pales attacks pine bark ... 30
mistaken for boll weevil ... 30

Page.
Icteria virens, enemy of boll weevil 146
Icterus bullocki, enemy of boll weevil 146
galbula, enemy of boll weevil 146
hypomelas, enemy of boll weevil in Cuba 145
spurius, enemy of boll weevil 146
Indigo, false. (*See* Baptisia.)
Insect enemies of boll weevil 136–145
Insecticides used against boll weevil 149–151
Iridomyrmex analis, enemy of boll weevil 140
prey of *Iridomyrmex humilis* 140
humilis enemy of boll weevil 140
Iridomyrmex analis 140
Monomorium pharaonis 140
Solenopsis geminata 140
Janovitch. (*See* Cotton, Egyptian.)
"Kelep." (See *Ectatomma tuberculatum*.)
Killdeer. (See *Oxyechus vociferus*.)
Kingbird. (See *Tyrannus tyrannus*.)
Lanius ludovicianus, enemy of boll weevil 146
Lariophagus texanus, enemy of boll weevil 142
Leaf worm (see also *Alabama argillacea*).
effect of defoliation on boll weevil 20
Live oak acorns attacked by *Balaninus victoriensis* 30
Lixus scrobicollis attacks stems of ragweed (Ambrosia) 30
mistaken for boll weevil 30
Machinery used against boll weevil 151–153
Macrocheles n. sp., enemy of boll weevil 137
Mallow, purple, host plant of *Anthonomus fulvus* 30
trailing. (*See* Callirhoe.)
Martin, purple. (See *Progne subis*.)
Meadowlark. (See *Sturnella magna*.)
western. (See *Sturnella neglecta*.)
Megaquiscalus major macrourus, enemy of boll weevil 146
Melospiza georgiana, enemy of boll weevil 146
Microbracon mellitor, enemy of boll weevil 142
Microdontomerus anthonomi, enemy of boll weevil 141
Mimus polyglottos, enemy of boll weevil 146
Mineral paint, futility against boll weevil 153
Mit afifi. (*See* Cotton, Egyptian.)
Mockingbird. (See *Mimus polyglottos*.)
Molasses, nonattractiveness to boll weevil 43
Molothrus ater, enemy of boll weevil 146
Monomorium minimum, enemy of boll weevil 140
pharaonis, enemy of boll weevil 140
prey of *Iridomyrmex humilis* 140
Morning glory pods attacked by *Rhyssematus palmacollis* 30
Muscivora forficata, enemy of boll weevil 146
Myiarchus crinitus, enemy of boll weevil 146
Myiophasia ænea, enemy of boll weevil 142
Nannus hyemalis, enemy of boll weevil 146
Nighthawk. (See *Chordeiles virginianus*.)
Nuttallornis borealis, enemy of boll weevil 146
Oats, duration of life of boll weevils fed thereon 48
Okra buds, duration of life of boll weevils fed thereon 48
leaf, duration of life of boll weevils fed thereon 48
tested as food plant of boll weevil 32
Opatrinus notus, enemy of boll weevil 138
Oriole, Baltimore. (See *Icterus galbula*.)
Bullock. (See *Icterus bullocki*.)
Cuban. (See *Icterus hypomelas*.)
orchard. (See *Icterus spurius*.)
Oxyechus vociferus, enemy of boll weevil 146
Pachylobius picivorus attacks pine branches and bark 30
mistaken for boll weevil 30
Parasites, factor in control of boll weevil 120
Paris green, futility against boll weevil 154

Page.
Passerculus sandwichensis, enemy of boll weevil 146
Passerella iliaca, enemy of boll weevil 146
Passerina ciris, enemy of boll weevil 146
Peaches attacked by *Conotrachelus nenuphar* 30
Pecan galls and nuts attacked by *Conotrachelus elegans* 30
Pediculoides sp., enemy of boll weevil 137
ventricosus, enemy of boll weevil 137
Penthestes carolinensis, enemy of boll weevil 146
Pepper, host plant of *Anthonomus eugenii* 30
plants, futility against boll weevil 155
Perilampus sp., enemy of boll weevil 141
Petrochelidon lunifrons, enemy of boll weevil 146
Pheidole crassicornis, enemy of boll weevil 140
sp., near *flavens*, enemy of boll weevil 140
Phœbe. (See *Sayornis phœbe*.)
Pigweed (see also *Amaranthus* spp.).
duration of life of boll weevils fed thereon 48
Pimpla sp., enemy of boll weevil 142
Pine bark attacked by *Hylobius pales* 30
branches and bark attacked by *Pachylobius picivorus* 30
Pissodes nemorensis 30
Pipilo erythrophthalmus, enemy of boll weevil 146
Pipit, American. (See *Anthus pensilvanicus*.)
Pissodes nemorensis, attacks pine branches and bark 30
mistaken for boll weevil 30
Plant control of boll weevil 132–136
Plover, upland. (See *Bartramia longicauda*.)
Plum curculio (see also *Conotrachelus nenuphar*).
host of *Sigalphus curculionis* 142
Plums attacked by *Conotrachelus nenuphar* 30
Poœcetes gramineus, enemy of boll weevil 146
Precipitation, effect on date of beginning emergence from hibernation by boll weevil 107–108
survival of hibernating boll weevils 112–114
Predators, factor in control of boll weevil 120
Prenolepis imparis, enemy of boll weevil 140
Prickly pear attacked by *Gerstæckeria nobilis* 30
Progne subis, enemy of boll weevil 146
Proliferation, control of boll weevil thereby 132–135
Pyrrhuloxia s. texana, enemy of boll weevil 146
Texan. (See *Pyrrhuloxia s. texana*.)
Quail. (See *Colinus virginianus*.)
Quarantine against boll weevil by Alabama 165
California 165
Egypt 168
Florida 165
Georgia 165–166
India 168
Louisiana 166
Mississippi 166
North Carolina 166–167
Oklahoma 167
Peru 168
Porto Rico 167
South Carolina 167–168
Tennessee 168
Texas 168
Quiscalus q. æneus, enemy of boll weevil 146
Ragweed. (*See* Ambrosia.)
Rainfall. (*See* Precipitation.)
Rains as agents in spread of boll weevil 91
Restriction of cotton planting now an impracticable means of boll weevil repression 156–157
Rhynchites mexicanus attacks rosebuds 30
mistaken for boll weevil 30
Rhyssematus palmacollis attacks morning glory pods 30
mistaken for boll weevil 30

Page.
Rice, duration of life of hibernated boll weevils fed thereon 48
Riparia riparia, enemy of boll weevil 146
Rosebuds attacked by *Rhynchites mexicanus* 30
Sage, wild. (*See* Croton.)
Sayornis phœbe, enemy of boll weevil 146
Seed cotton, factor in dissemination of boll weevil 91–92
Shrike, loggerhead. (See *Lanius ludovicianus.*)
Sideranthus attacked by *Desmoris scapalis* 30
Sigalphus curculionis, enemy of boll weevil 142
                plum curculio (*Conotrachelus nenuphar*) 142
Solanum rostratum stalks attacked by *Trichobaris texana* 30
Solenopsis geminata diabola, enemy of boll weevil 139–140
                prey of *Iridomyrmex humilis* 140
        molesta, enemy of boll weevil 140
        texana, enemy of boll weevil 140
Sorghum cane, duration of life of boll weevils fed thereon 48
Spanish moss as hibernation shelter for boll weevil 101
    thistle. (See *Solanum rostratum.*)
Sparrow, field. (See *Spizella pusilla.*)
    fox. (See *Passerella iliaca.*)
    lark. (See *Chondestes grammacus.*)
    savanna. (See *Passerculus sandwichensis.*)
    swamp. (See *Melospiza georgiana.*)
    vesper. (See *Poœcetes gramineus.*)
    white-throated. (See *Zonotrichia albicollis.*)
Spilochalcis sp., enemy of boll weevil 141
Spiza americana, enemy of boll weevil 146
Spizella pusilla, enemy of boll weevil 146
Spraying, futility against boll weevil 153
Stagmomantis limbata, enemy of boll weevil 137
Stalk-cutting device for cotton 158
Strawberry, host plant of *Anthonomus signatus* 30
Sturnella magna, enemy of boll weevil 146
    neglecta, enemy of boll weevil 146
Sugar, nonattractiveness to boll weevil 43
Sulphur, futility against boll weevil 153
Sunflower (*see also* Helianthus).
    duration of life of boll weevils fed thereon 48
Swallow, bank. (See *Riparia riparia.*)
    barn. (See *Hirundo erythrogastra.*)
    cliff. (See *Petrochelidon lunifrons.*)
Temperature, effect upon date of beginning emergence from hibernation by
                boll weevil 107–108
            entering hibernation 97–98
        duration of egg stage of boll weevil 62–63
                larval stage of boll weevil 66
                pupal stage of boll weevil 67–68
        life cycle of boll weevil 70–72
        locomotion of boll wevil 43–44
        oviposition of boll weevil 58–59
        survival of hibernating boll weevils 112–114
    fatal variations for boll weevil 129–131
    relations to boll weevil 125–131
    zone of activity for boll weevil 127
        fatality, lower, for boll weevil 128–131
            upper, for boll weevil 126
        hibernation for boll weevil 127–128
Tetrastichus hunteri, enemy of boll weevil 142
Thistle, Spanish. (*See* Spanish thistle.)
Thrasher, brown. (See *Toxostoma rufum.*)
Thryomanes bewicki, enemy of boll weevil 146
Thryothorus ludovicianus, enemy of boll weevil 146
Tie vine, duration of life of boll weevils fed thereon 48
Tillandsia usneoides. (*See* Spanish moss.)
Titmouse, black-crested. (See *Bæolophus atricristatus.*)
    tufted. (See *Bæolophus bicolor.*)

Page.

- Tobacco, futility against boll weevil ... 155
  - stalks attacked by *Trichobaris mucorea* ... 30
- Towhee. (See *Pipilo erythrophthalmus*.)
- *Toxostoma rufum*, enemy of boll weevil ... 146
- Trapping at lights, futility against boll weevil ... 154
- *Trichobaris mucorea* attacks tobacco stalks ... 30
  - mistaken for boll weevil ... 30
  - *texana* attacks Spanish thistle stalks (*Solanum rostratum*) ... 30
    - mistaken for boll weevil ... 30
- *Tychius sordidus* attacks pods of false indigo (Baptisia) ... 30
  - mistaken for boll weevil ... 30
- *Tyrannus tyrannus*, enemy of boll weevil ... 146
- *Tyroglyphus breviceps*, enemy of boll weevil ... 137
- United States statute regarding boll weevil ... 164
- *Urosigalphus anthonomi*, enemy of boll weevil ... 142
  - *schwarzi*, enemy of boll weevil ... 142
  - sp., enemy of boll weevil ... 142
- Vehicles, factors in dissemination of boll weevil ... 93
- Warbler, myrtle. (See *Dendroica coronata*.)
  - yellow. (See *Dendroica æstiva*.)
- Water, duration of life of boll weevils fed thereon ... 48
  - hibernated boll weevils fed thereon ... 48
- Windstorms as agents in spread of boll weevil ... 90
- Wren, Bewick. (See *Thryomanes bewicki*.)
  - Carolina. (See *Thryothorus ludovicianus*.)
  - winter. (See *Nannus hyemalis*.)
- Xanthium roots attacked by *Baris transversa* ... 30
- Yellowthroat, Maryland. (See *Geothlypis trichas*.)
- *Zonotrichia albicollis*, enemy of boll weevil ... 146

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